THE
BIOLOGICAL BULLETIN

PUBLISHED BY
THE MARINE BIOLOGICAL LABORATORY

Editorial Board

E. G. CONKLIN, Princeton University
E. N. HARVEY, Princeton University
SELIG HECHT, Columbia University
LEIGH HOADLEY, Harvard University
L. IRVING, Swarthmore College
M. H. JACOBS, University of Pennsylvania
H. S. JENNINGS, Johns Hopkins University
FRANK R. LILLIE, University of Chicago
CARL R. MOORE, University of Chicago
GEORGE T. MOORE, Missouri Botanical Garden
G. H. PARKER, Harvard University
A. C. REDFIELD, Harvard University
F. SCHRADER, Columbia University
DOUGLAS WHITAKER, Stanford University

H. B. STEINBACH, Washington University
Managing Editor

VOLUME 91
AUGUST TO DECEMBER, 1946

Printed and Issued by
LANCASTER PRESS, Inc.
PRINCE & LEMON STS.
LANCASTER, PA.

THE BIOLOGICAL BULLETIN is issued six times a year at the Lancaster Press, Inc., Prince and Lemon Streets, Lancaster, Pennsylvania.

Subscriptions and similar matter should be addressed to The Biological Bulletin, Marine Biological Laboratory, Woods Hole, Massachusetts. Agent for Great Britain: Wheldon and Wesley, Limited, 2, 3 and 4 Arthur Street, New Oxford Street, London, W. C. 2. Single numbers, $1.75. Subscription per volume (three issues), $4.50.

Communications relative to manuscripts should be sent to the Managing Editor, Marine Biological Laboratory, Woods Hole, Massachusetts, between July 1 and September 1, and to the Department of Zoology, Washington University, St. Louis, Missouri, during the remainder of the year.

Entered as second-class matter May 17, 1930, at the post office at Lancaster, Pa., under the Act of August 24, 1912.

LANCASTER PRESS, INC., LANCASTER, PA

CONTENTS

No. 1. August, 1946

PAGE

Annual Report of the Marine Biological Laboratory 1

Pomerat, C. M., and C. M. Weiss
The influence of texture and composition of surface on the attachment of sedentary marine organisms 57

Scott, Sister Florence Marie
The developmental history of Amaroecium constellatum. II. Organogenesis of the larval action system 66

Giese, Arthur C.
Comparative sensitivity of sperm and eggs to ultraviolet radiations ... 81

Carriker, Melbourne Romaine
Observations on the functioning of the alimentary system of the snail Lymnaea stagnalis appressa Say 88

Chen, Tze-Tuan
Temporary pair formation in Paramecium bursaria 112

No. 2. October, 1946

Weisz, Paul B.
The space-time pattern of segment formation in Artemia salina 119

Jakus, M. A., and C. E. Hall
Electron microscope observations of the trichocysts and cilia in Paramecium 141

Pease, Daniel C.
Hydrostatic pressure effects upon the spindle figure and chromosome movement. II. Experiments on the meiotic divisions of Tradescantia pollen mother cells 145

Brown, Frank A. Jr., and Lorraine M. Saigh
The comparative distribution of two chromatophorotropic hormones (CDH and CBLH) in Crustacean nervous systems 170

Morrison, Peter R.
Physiological observations on water loss and oxygen consumption in Peripatus 181

Kozloff, Eugene N.
Studies on ciliates of the family Ancistrocomidae Chatton and Lowff (order Holotricha, suborder Thigmotricha). III. Ancistrocoma pelseneeri Chatton and Lwoff, Ancistrocoma dissimilis sp. nov., and Hypocomagalma pholadidis sp. nov. 189

Kozloff, Eugene N.
Studies on ciliates of the family Ancistrocomidae Chatton and Lwoff (order Holotricha, suborder Thigmotricha). IV. Heterocineta janickii Jarocki, Heterocineta goniobasidis sp. nov., Heterocineta fluminicolae sp. nov., and Enerthecoma properans Jarocki 200

ABSTRACTS OF SCIENTIFIC PAPERS PRESENTED AT THE MARINE BIOLOGICAL LABORATORY, SUMMER OF 1946 210
PAPERS PRESENTED AT THE MEETING OF THE SOCIETY OF GENERAL PHYSIOLOGISTS 236

No. 3. DECEMBER, 1946

WHITING, P. W.
A strongly intersexual female in Habrobracon 243
TOBIAS, J. M., AND J. J. KOLLROS
Loci of action of DDT in the cockroach (Periplaneta americana) 247
BEERS, C. D.
Tillina magna: Micronuclear number, encystment and vitality in diverse clones; capabilities of amicronucleate races 256
SCOTT, ALLAN
The effect of low temperature and of hypotonicity on the morphology of the cleavage furrow in Arbacia eggs 272
BODENSTEIN, DIETRICH
Developmental relations between genital ducts and gonads in Drosophila 288
LEHMAN, H. E.
A histological study of Syndisyrinx franciscanus, gen. et sp. nov., an endoparasitic rhabdocoel of the sea urchin, Strongylocentrotus franciscanus 295
SPOOR, W. A.
A quantitative study of the relationship between the activity and oxygen consumption of the goldfish, and its application to the measurement of respiratory metabolism in fishes 312

Volume 91 Number 1

SEP 1 6 1946

Science Library

THE BIOLOGICAL BULLETIN

PUBLISHED BY
THE MARINE BIOLOGICAL LABORATORY

Editorial Board

E. G. CONKLIN, Princeton University
E. N. HARVEY, Princeton University
SELIG HECHT, Columbia University
LEIGH HOADLEY, Harvard University
L. IRVING, Swarthmore College
M. H. JACOBS, University of Pennsylvania
H. S. JENNINGS, Johns Hopkins University
FRANK R. LILLIE, University of Chicago
CARL R. MOORE, University of Chicago
GEORGE T. MOORE, Missouri Botanical Garden
G. H. PARKER, Harvard University
A. C. REDFIELD, Harvard University
F. SCHRADER, Columbia University
DOUGLAS WHITAKER, Stanford University
H. B. STEINBACH, Washington University
Managing Editor

AUGUST, 1946

Printed and Issued by
LANCASTER PRESS, Inc.
PRINCE & LEMON STS.
LANCASTER, PA.

BOOKS—WAR VICTIMS

DURING THE WAR, the libraries of half the world were destroyed in the fires of battle and in the fires of hate and fanaticism. Where they were spared physical damage, they were impoverished by isolation. There is an urgent need —now—for the printed materials which are basic to the reconstruction of devastated areas and which can help to remove the intellectual blackout of Europe and the Orient.

There is need for a pooling of resources, for coordinated action in order that the devastated libraries of the world may be restocked as far as possible with needed American publications. The American Book Center for War Devastated Libraries, Inc., has come into being to meet this need. It is a program that is born of the combined interests of library and educational organizations, of government agencies, and of many other official and non-official bodies in the United States.

The American Book Center is collecting and is shipping abroad scholarly books and periodicals which will be useful in research and necessary in the physical, economic, social and industrial rehabilitation and reconstruction of Europe and the Far East.

The Center cannot purchase books and periodicals; it must depend upon gifts from individuals, institutions, and organizations. Each state will be organized to participate in the program through the leadership of a state chairman. Other chairmen will organize interest in the principal subject fields. Cooperation with these leaders or direct individual contributions are welcomed.

WHAT IS NEEDED: Shipping facilities are precious and demand that all materials be carefully selected. Emphasis is placed upon publications issued during the past decade, upon scholarly books which are important contributions to their fields, upon periodicals (even incomplete volumes) of significance, upon fiction and non-fiction of distinction. All subjects—history, the social sciences, music, fine arts, literature, and especially the sciences and technologies—are wanted.

WHAT IS NOT NEEDED: Textbooks, out-dated monographs, recreational reading, books for children and young people, light fiction, materials of purely local interest, popular magazines such as *Time, Life, National Geographic,* etc., popular non-fiction of little enduring significance such as Gunther's *Inside Europe,* Haliburton's *Royal Road to Romance,* etc. Only carefully selected federal and local documents are needed, and donors are requested to write directly to the Center with regard to specific documents.

HOW TO SHIP: All shipments should be sent PREPAID via the cheapest means of transportation to THE AMERICAN BOOK CENTER, C/O THE LIBRARY OF CONGRESS, WASHINGTON 25, D. C. Although the Center hopes that donors will assume the costs of transportation of their materials to Washington, when this is not possible reimbursement will be made upon notification by card or letter of the amount due. THE CENTER CANNOT ACCEPT MATERIAL WHICH IS SENT COLLECT. Reimbursement cannot be made for packing or other charges beyond actual transportation. When possible, periodicals should be tied together by volume. It will be helpful if missing issues are noted on incomplete volumes.

Vol. 91, No. 1 August, 1946

THE BIOLOGICAL BULLETIN

PUBLISHED BY THE MARINE BIOLOGICAL LABORATORY

THE MARINE BIOLOGICAL LABORATORY

FORTY-EIGHTH REPORT, FOR THE YEAR 1945—FIFTY-EIGHTH YEAR

I. TRUSTEES AND EXECUTIVE COMMITTEE (AS OF AUGUST 14, 1945) 1
STANDING COMMITTEES
II. ACT OF INCORPORATION 3
III. BY-LAWS OF THE CORPORATION 4
IV. REPORT OF THE TREASURER 5
V. REPORT OF THE LIBRARIAN 9
VI. REPORT OF THE DIRECTOR 11
Statement 11
Addenda:
1. Publications from this Laboratory during the years 1941–1945.. 13
2. The Staff 33
3. Investigators and Students 35
4. Tabular View of Attendance, 1941–1945 41
5. Subscribing and Co-operating Institutions 42
6. Evening Lectures 42
7. Shorter Scientific Papers 43
8. Members of the Corporation 44

I. TRUSTEES

EX OFFICIO

FRANK R. LILLIE, *President Emeritus of the Corporation,* The University of Chicago
LAWRASON RIGGS, *President of the Corporation,* 120 Broadway, New York City
E. NEWTON HARVEY, *Vice President of the Corporation,* Princeton University
CHARLES PACKARD, *Director,* Marine Biological Laboratory
OTTO C. GLASER, *Clerk of the Corporation,* Amherst College
DONALD M. BRODIE, *Treasurer,* 522 Fifth Avenue, New York City

EMERITUS

E. G. CONKLIN, Princeton University
B. M. DUGGAR, University of Wisconsin
W. E. GARREY, Vanderbilt University
R. A. HARPER, Columbia University
ROSS G. HARRISON, Yale University
H. S. JENNINGS, University of California
F. P. KNOWLTON, Syracuse University

R. S. LILLIE, The University of Chicago
*C. E. MCCLUNG, University of Pennsylvania
S. O. MAST, Johns Hopkins University
A. P. MATHEWS, University of Cincinnati
*T. H. MORGAN, California Institute of Technology
W. J. V. OSTERHOUT, Rockefeller Institute
G. H. PARKER, Harvard University
W. B. SCOTT, Princeton University

TO SERVE UNTIL 1949

W. R. AMBERSON, University of Maryland School of Medicine
P. B. ARMSTRONG, Syracuse University
L. G. BARTH, Columbia University
S. C. BROOKS, University of California
W. C. CURTIS, University of Missouri
H. B. GOODRICH, Wesleyan University
A. C. REDFIELD, Harvard University
C. C. SPEIDEL, University of Virginia

TO SERVE UNTIL 1948

ERIC G. BALL, Harvard University Medical School
R. CHAMBERS, Washington Square College, New York University
EUGENE F. DUBOIS, Cornell University Medical College
COLUMBUS ISELIN, Woods Hole Oceanographic Institution
C. W. METZ, University of Pennsylvania
H. H. PLOUGH, Amherst College
E. W. SINNOTT, Yale University
W. R. TAYLOR, University of Michigan

TO SERVE UNTIL 1947

W. C. ALLEE, The University of Chicago
G. H. A. CLOWES, Lilly Research Laboratory
P. S. GALTSOFF, U. S. Fish and Wild Life Service
L. V. HEILBRUNN, University of Pennsylvania
LAURENCE IRVING, Swarthmore College
J. H. NORTHROP, Rockefeller Institute
A. H. STURTEVANT, California Institute of Technology
LORANDE L. WOODRUFF, Yale University

TO SERVE UNTIL 1946

DUGALD E. S. BROWN, New York University
E. R. CLARK, University of Pennsylvania
OTTO C. GLASER, Amherst College
E. N. HARVEY, Princeton University
M. H. JACOBS, University of Pennsylvania
A. K. PARPART, Princeton University
FRANZ SCHRADER, Columbia University
B. H. WILLIER, Johns Hopkins University

EXECUTIVE COMMITTEE OF THE BOARD OF TRUSTEES

LAWRASON RIGGS, *Ex officio, Chairman*
E. N. HARVEY, *Ex officio*

* Deceased.

D. M. Brodie, *Ex officio*
Charles Packard, *Ex officio*
P. B. Armstrong, to serve until 1947
L. G. Barth, to serve until 1946
P. S. Galtsoff, to serve until 1947
Wm. Randolph Taylor, to serve until 1946

The Library Committee

A. C. Redfield, *Chairman*
E. G. Ball
S. C. Brooks
M. E. Krahl
J. W. Mavor

The Apparatus Committee

E. P. Little, *Chairman*
C. L. Claff
G. Failla
S. E. Hill
A. K. Parpart

The Supply Department Committee

D. A. Marsland, *Chairman*
P. B. Armstrong
P. S. Galtsoff
R. T. Kempton
Charles Packard

The Evening Lecture Committee

F. M. Landis, *Chairman*
Charles Packard

The Instruction Committee

H. B. Goodrich, *Chairman*
W. C. Allee
S. C. Brooks
Viktor Hamburger
Charles Packard, *Ex officio*

The Buildings and Grounds Committee

E. G. Ball, *Chairman*
D. P. Costello
Mrs. E. N. Harvey
Roberts Rugh
Mrs. C. C. Speidel

II. ACT OF INCORPORATION

No. 3170

Commonwealth of Massachusetts

Be It Known, That whereas Alpheus Hyatt, William Sanford Stevens, William T. Sedgwick, Edward G. Gardiner, Susan Minns, Charles Sedgwick Minot, Samuel Wells, William G. Farlow, Anna D. Phillips, and B. H. Van Vleck have associated themselves with the intention of forming a Corporation under the name of the Marine Biological Laboratory, for the purpose of establishing and maintaining a laboratory or station for

scientific study and investigation, and a school for instruction in biology and natural history, and have complied with the provisions of the statutes of this Commonwealth in such case made and provided, as appears from the certificate of the President, Treasurer, and Trustees of said Corporation, duly approved by the Commissioner of Corporations, and recorded in this office;

Now, therefore, I, HENRY B. PIERCE, Secretary of the Commonwealth of Massachusetts, *do hereby certify* that said A. Hyatt, W. S. Stevens, W. T. Sedgwick, E. G. Gardiner, S. Minns, C. S. Minot, S. Wells, W. G. Farlow, A. D. Phillips, and B. H. Van Vleck, their associates and successors, are legally organized and established as, and are hereby made, an existing Corporation, under the name of the MARINE BIOLOGICAL LABORATORY, with the powers, rights, and privileges, and subject to the limitations, duties, and restrictions, which by law appertain thereto.

Witness my official signature hereunto subscribed, and the seal of the Commonwealth of Massachusetts hereunto affixed, this twentieth day of March, in the year of our Lord One Thousand Eight Hundred and Eighty-Eight.

[SEAL]

HENRY B. PIERCE,
Secretary of the Commonwealth.

III. BY-LAWS OF THE CORPORATION OF THE MARINE BIOLOGICAL LABORATORY

I. The members of the Corporation shall consist of persons elected by the Board of Trustees.

II. The officers of the Corporation shall consist of a President, Vice President, Director, Treasurer, and Clerk.

III. The Annual Meeting of the members shall be held on the second Tuesday in August in each year, at the Laboratory in Woods Hole, Massachusetts, at 11:30 A.M., and at such meeting the members shall choose by ballot a Treasurer and a Clerk to serve one year, and eight Trustees to serve four years, and shall transact such other business as may properly come before the meeting. Special meetings of the members may be called by the Trustees to be held at such time and place as may be designated.

IV. Twenty-five members shall constitute a quorum at any meeting.

V. Any member in good standing may vote at any meeting, either in person or by proxy duly executed.

VI. Inasmuch as the time and place of the Annual Meeting of members are fixed by these By-laws, no notice of the Annual Meeting need be given. Notice of any special meeting of members, however, shall be given by the Clerk by mailing notice of the time and place and purpose of such meeting, at least fifteen (15) days before such meeting, to each member at his or her address as shown on the records of the Corporation.

VII. The Annual Meeting of the Trustees shall be held on the second Tuesday in August in each year, at the Laboratory in Woods Hole, Mass., at 10 A.M. Special meetings of the Trustees shall be called by the President, or by any seven Trustees, to be held at such time and place as may be designated, and the Secretary shall give notice thereof by written or printed notice, mailed to each Trustee at his address as shown on the records of the Corporation, at least one (1) week before the meeting. At such special meeting only matters stated in the notice shall be considered. Seven Trustees of those eligible to vote shall constitute a quorum for the transaction of business at any meeting.

VIII. There shall be three groups of Trustees:

(A) Thirty-two Trustees chosen by the Corporation, divided into four classes, each to serve four years; and in addition there shall be two groups of Trustees as follows:

(B) Trustees ex officio, who shall be the President and Vice President of the Corporation, the Director of the Laboratory, the Associate Director, the Treasurer, and the Clerk;

(C) Trustees Emeritus, who shall be elected from the Trustees by the Corporation. Any regular Trustee who has attained the age of seventy years shall continue to serve as Trustee until the next Annual Meeting of the Corporation, whereupon his office as regular Trustee shall become vacant and be filled by election by the Corporation and he shall become eligible for election as Trustee *Emeritus* for life. The Trustees *ex officio* and *Emeritus* shall have all the rights of the Trustees except that Trustees *Emeritus* shall not have the right to vote.

The Trustees and officers shall hold their respective offices until their successors are chosen and have qualified in their stead.

IX. The Trustees shall have the control and management of the affairs of the Corporation; they shall elect a President of the Corporation who shall also be Chairman of the Board of Trustees; and shall also elect a Vice President of the Corporation who shall also be the Vice Chairman of the Board of Trustees; they shall appoint a Director of the Laboratory; and they may choose such other officers and agents as they may think best; they may fix the compensation and define the duties of all the officers and agents; and may remove them, or any of them, except those chosen by the members, at any time; they may fill vacancies occurring in any manner in their own number or in any of the offices. The Board of Trustees shall have the power to choose an Executive Committee from their own number, and to delegate to such Committee such of their own powers as they may deem expedient. They shall from time to time elect members to the Corporation upon such terms and conditions as they may think best.

X. Any person interested in the Laboratory may be elected by the Trustees to a group to be known as Associates of the Marine Biological Laboratory.

XI. The consent of every Trustee shall be necessary to dissolution of the Marine Biological Laboratory. In case of dissolution, the property shall be disposed of in such manner and upon such terms as shall be determined by the affirmative vote of two-thirds of the Board of Trustees.

XII. The account of the Treasurer shall be audited annually by a certified public accountant.

XIII. These By-laws may be altered at any meeting of the Trustees, provided that the notice of such meeting shall state that an alteration of the By-laws will be acted upon.

IV. THE REPORT OF THE TREASURER

To the Trustees of the Marine Biological Laboratory:

Gentlemen:

Herewith is my report as Treasurer of the Marine Biological Laboratory for the year 1945.

The accounts have been audited by Messrs. Seamans, Stetson, and Tuttle, certified public accountants. A copy of their report is on file at the Laboratory and inspection of it by members of the Corporation will be welcomed.

The principal summaries of their report—The Balance Sheet, Statement of Income and Expense, and Current Surplus Account—are appended hereto as Exhibits A, B, and C.

The following are some general statements and observations based on the detailed reports:

I. Assets

1. Endowment Assets

As of December 31, 1945, the total book value of all the Endowment Assets, including the Scholarship Funds, was $966,772.16, a loss for the year of $17,128.41. The decline was due, as in the last two years, to losses on the mortgage participations on New York City realty held in the Trust Funds.

At the end of the year $831,993.01 was invested in marketable securities (bonds, preferred stocks and common stocks) with a market value of $910,162.31. $125,753.85 was invested in mortgage participations on New York City real estate. $9,025.30 was in uninvested principal cash.

The Treasurer's estimate of the actual value of the $125,753.85 in mortgage notes and participations held on December 31 is $85,750.00. With the market value of $910,162.31 on marketable securities and the $9,025.30 in cash this makes a total current valuation of $1,004,937.61 compared with total book value of $966,772.16.

The increase for the year in market values, $75,454.79, is largely due to the rise in common stock prices.

2. Plant Assets

There were no changes of any consequence in Plant Assets during the year. The Reserve Fund was increased nearly $10,000.00 to a total of $26,830.71 by the transfer of the Crane Co. dividends, part of the General Biological Supply House dividends and other items of current income.

3. Current Assets

The total of current assets increased $10,730.68 during 1945 to a total of $212,970.35. Current Liabilities at the end of the year were $2,754.70. Current Surplus increased $12,277.94 to a total of $196,337.90.

II. Income and Expenditures

The return to more normal operations for the Laboratory last summer resulted in larger totals for both income and expense items. Total income was $182,818.23, total expense including depreciation reserves of $26,968.12 was $173,044.95, giving a net surplus for the year of $9,773.28.

EXHIBIT A

Marine Biological Laboratory Balace Sheet, December 31, 1945

Assets

Endowment Assets and Equities:		
Securities and Cash in Hands of Central Hanover Bank and Trust Company, New York, Trustee	$ 950,130.04	
Securities and Cash in Minor Funds	16,642.12	
		$ 966,772.16

Plant Assets:			
Land	$ 111,425.38		
Buildings	1,326,345.54		
Equipment	187,837.87		
Library	337,266.01		
	$1,962,874.80		
Less Reserve for Depreciation	677,140.22	$1,285,734.58	
Reserve Fund, Securities and Cash		26,830.71	
Book Fund, Securities and Cash		18,282.46	
			$1,330,847.75
Current Assets:			
Cash		$ 30,467.02	
Accounts Receivable		20,396.05	
Inventories:			
Supply Department	$ 44,441.66		
Biological Bulletin	20,117.40	64,559.06	
Investments:			
Devil's Lane Property	$ 46,556.99		
Gansett Property	1,749.92		
Stock in General Biological Supply House, Inc.	12,700.00		
Other Investment Stocks	20,095.00		
Retirement Fund	11,517.82	92,619.73	
Prepaid Insurance		4,033.08	
Items in Suspense		895.41	
			$ 212,970.35
Total Assets			$2,510,590.26
Liabilities			
Endowment Funds:			
Endowment Funds	$ 948,646.82		
Reserve for Amortization of Bond Premiums	1,483.22		
		$ 950,130.04	
Minor Funds		16,642.12	
			$ 966,772.16
Plant Funds:			
Mortgage Notes Payable		$ 5,000.00	
Donations and Gifts	$1,172,564.04		
Other Investments in Plant from Gifts and Current Funds	153,283.71		
		$1,325,847.75	
			$1,330,847.75
Current Liabilities and Surplus:			
Accounts Payable		$ 2,754.70	
Items in Suspense		1,799.63	
Reserve for Repairs and Replacements		12,078.12	
Current Surplus		196,337.90	
			$ 212,970.35
Total Liabilities			$2,510,590.26

EXHIBIT B

Marine Biological Laboratory Income and Expense, Year Ended December 31, 1945

	Total		Net	
	Expense	Income	Expense	Income
Income:				
General Endowment Fund		$ 32,214.07		$ 32,214.07
Library Fund		9,479.18		9,479.18
Donations		755.00		755.00
Instruction	$ 9,554.39	7,220.00	$ 2,334.39	
Research	4,550.59	17,434.24		12,883.65
Evening Lectures	86.35		86.35	
Biological Bulletin and Membership Dues	6,393.65	8,775.63		2,381.98
Supply Department	39,255.03	47,812.56		8,557.53
Mess	24,146.52	20,750.36	3,396.16	
Dormitories	27,443.23	14,547.91	12,895.32	
(Interest and Depreciation charged to above 3 Departments)	(25,574.03)			25,574.03
Dividends, General Biological Supply House, Inc.		14,732.00		14,732.00
Dividends, Other Investment Stocks		725.00		725.00
Rents:				
Bar Neck Property	767.65	6,000.00		5,232.35
Janitor House	30.89	360.00		329.11
Danchakoff Cottages	240.86	275.00		34.14
Sale of Library Duplicates, Micro Film, etc.		344.74		344.74
Microscope and Apparatus Rental		1,372.54		1,372.54
Sundry Income		20.00		20.00
Maintenance of Plant:				
Buildings and Grounds	23,642.27		23,642.27	
Apparatus Department	4,911.52		4,911.52	
Chemical Department	2,265.30		2,265.30	
Library Expense	6,487.95		6,487.95	
Workmen's Compensation Insurance	526.63		526.63	
Truck Expense	238.60		238.60	
Bay Shore Property	92.78		92.78	
Great Cedar Swamp	21.00		21.00	
General Expenses:				
Administration Expense	15,168.99		15,168.99	
Endowment Fund Trustee and Safe-Keeping	1,028.45		1,028.45	
Bad Debts	375.97		375.97	
Special Repairs on account of 1944 Hurricane Damage	4,297.24		4,297.24	
Interest	125.00		125.00	
Reserve for Depreciation	26,968.12		26,968.12	
	$173,044.95	$182,818.23	$104,862.04	$114,635.32
Excess of Income over Expense carried to Current Surplus	9,773.28		9,773.28	
	$182,818.23		$114,635.32	

EXHIBIT C

MARINE BIOLOGICAL LABORATORY, CURRENT SURPLUS ACCOUNT, YEAR ENDED DECEMBER 31, 1945

Balance January 1, 1945			$184,059.96
Add:			
Excess of Income over Expense for Year as shown in Exhibit B..		$ 9,773.28	
Gain on Gansett Lots Sold		464.18	
Bad Debts Recovered		82.23	
Mortgage Payable, Transferred to Plant Funds		5,000.00	
Reserve for Depreciation Charged to Plant Funds		26,968.12	42,287.81
			$226,347.77
Deduct:			
Payments from Current Funds during Year for Plant Assets as shown in Schedule IV:			
Buildings	$ 7,402.65		
Equipment	4,462.50		
Library	7,500.43		
	$19,365.58		
Less Received for Plant Assets Sold	5,600.00		
		$13,765.58	
Pensions Paid	$ 3,460.00		
Loss on Retirement Fund Securities	847.32		
	$ 4,307.32		
Less Retirement Fund Income	311.79		
		$ 3,995.53	
Transfers to Reserve Fund:			
Portion of Dividends from General Biological Supply House, Inc.	$ 2,500.00		
Dividends from Crane Co.	625.00		
Income from Operation and Sale of Property 445–51 W. 23rd and 450–2 W. 24th Sts., N. Y. C.	8,947.72		
Gansett Property Profits, 1944	176.04	12,248.76	30,009.87
Balance, December 31, 1945			$196,337.90

Respectfully submitted,

DONALD M. BRODIE,
Treasurer

V. REPORT OF THE LIBRARIAN

The sum $12,262.54 appropriated to the library in 1945 was expended as follows: books, $469.99; serials, $2,625.79; binding, $577.60; express, $43.22; supplies, $147.84; salaries, $7,262.54 ($1,150 of this sum was contributed by the Woods Hole Oceanographic Institution); back sets, $1,104.98; insurance, $45.00;

sundries, $5.00; total, $12,281.96. The cash receipts of the library totalled $344.74: for microfilms, $220.34 ($62.17 expenses paid by the library and accounted above under "supplies"); sale of duplicates, $122.74; sale of the "Serial List," Biological Bulletin supplement number, $1.66. This sum, $344.74, reverts to the laboratory and does not include rent payments for library readers which are collected by the main office. There were 49 library readers accommodated in the library during the summer of 1945.

Of the Carnegie of New York Fund, $126.35 was expended for the completion of one journal and the partial completion of another.

The sum appropriated by the Woods Hole Oceanographic Institution in 1945 for purchases was $800. A balance of $949.39 remaining from 1944 made an available total of $1,749.39. Of this sum $947.12 was expended, leaving a balance of $802.27 towards future purchases. In addition to the above, the Woods Hole Oceanographic Institution contributed $1,150 (see above under salaries).

During 1945 the library received 902 current journals: 279 (8 new) by subscription to the Marine Biological Laboratory; 30 (7 new) to the Woods Hole Oceanographic Institution; exchanges 352 (6 new; 145 reinstated foreign) and 58 (35 foreign reinstated) with the Woods Hole Oceanographic Institution publications; 177 as gifts to the former and 6 to the latter. The library acquired 206 books: 77 by purchase of the Marine Biological Laboratory; 44 by purchase of the Woods Hole Oceanographic Institution; 10 gifts by the authors; 46 gifts by the publishers; 20 by miscellaneous donors and 9 from Miss Jane Strong. There were 22 back sets of serial publications completed: 14 purchased by the Marine Biological Laboratory (one with the Carnegie Fund); 2 by the Woods Hole Oceanographic Institution; 5 by exchange of the "Biological Bulletin" and one by exchange of duplicate material. Partially completed sets were 54: purchased by the Marine Biology Laboratory, 27 (1 by the Carnegie Fund); purchased by the Woods Hole Oceanographic Institution, 2; by exchange with the "Biological Bulletin," 2; by gift and exchange of duplicate material, 23.

The reprint additions to the library were 4,620; current of 1944, 604; current of 1945, 64; and of previous dates, 3,952. A total of 6,390, 2,130 not duplicates of our holdings, were presented to the library; 4,295 by Mrs. Meigs; 67 by Dr. H. G. Cassidy; 627 by the University of Utah; 26 by Dr. B. M. Davis; and 1,375 by Dr. L. C. Wyman. The large collection of Dr. Garrey's reprints presented last year have not as yet been counted nor started on the way toward cataloguing.

At the end of the year 1945 the library contained 53,990 bound volumes and 137,674 reprints.

Readers of the library report will be glad to note the number of foreign exchanges that have already been reinstated during 1945, both for the "Biological Bulletin" and for the Woods Hole Oceanographic Institution publications: 145 for the former and 35 for the latter. Next year's report will probably show the pre-war number reinstated save only for Germany and perhaps for Russia since we get very poor response from that country. Nor have we heard anything in regard to the German journals on order with Otto Harrassowitz which are apparently stalled if not destroyed in Leipzig. The library committee that is working with the State Department to get these released has nothing so far to report to this library.

VI. REPORT OF THE DIRECTOR

To the Trustees of The Marine Biological Laboratory:

Gentlemen:

I herewith submit a report on the fifty-eighth session of the Marine Biological Laboratory.

1. Attendance

Since 1943 our total attendance has increased from the low point reached that year. In 1944 it was 53 per cent of the pre-war average of 490; in 1945 it was 63 per cent. This increase is found among the independent investigators and the students; the beginning investigators and research assistants, who, as I explained in the last report, belong in one group, are still sparsely represented. In 1945 there were only 36, whereas the pre-war average was 130. The advance registration for 1946 shows an encouraging increase in this group. Many of the applicants are veterans who are taking advantage of Government funds provided under the G. I. Bill of Rights.

2. Building Repairs

One of the inevitable effects of the war has been the deterioration of our buildings. Lack of materials and labor has up until now prevented all but the most essential repairs from being made. Fortunately, we are now able to begin to put our house in order, in spite of the shortage of some critical materials. To determine what work should be done, a Committee on Special Repairs, under the able leadership of Mr. C. L. Claff, conducted a thorough survey of all of the buildings and made detailed recommendations. The report, a model of completeness as drawn up by Mr. Claff, calls for the ultimate expenditure of approximately $145,000 for present repairs and future desirable improvements not only in the buildings but also in equipment for the Apparatus Department and the Supply Department.

The Executive Committee voted to expend the entire Reserve Fund, amounting to $25,000, and all but a minimum of the current cash on hand for making the most urgently needed repairs at once. It also laid plans for securing outside funds with which to complete the changes called for in the report, and to purchase apparatus. In addition, funds for a new building and for additional endowment are to be sought.

Many of the essential repairs have already been made. The Mess kitchen, never properly restored after the Navy occupation, is now in good condition, and improvements in the dining room have been made. The Botany Building, unused for several seasons, has been put to rights with new plumbing, wall tables, shelves, and other fixtures. Replacements have been made in the Supply Department and Rockefeller Building; hot water systems are installed in the residences heretofore not so provided; and much painting has been done. This work was accomplished in large measure by our permanent staff, under the direction of Mr. MacNaught. All the men worked faithfully and energetically, and have completed the assigned tasks in a most satisfactory manner. It is hoped that waterproofing of the Crane and Brick Buildings may be completed before the 1946 season begins. As soon as this has been satisfactorily finished, those Laboratory rooms which have been damaged by water can be made presentable.

3. The Housing Problem

An unexpected outcome of war-time activities is the housing shortage. Before the war our residences and the houses in the village could accommodate 450 to 500 persons during the course of a summer. But when the Oceanographic Institution embarked on extensive defense projects, the number of its workers increased from comparatively few to upwards of 250, most of whom are year round residents. They now occupy most of the available houses in the village; some are forced to live as far away as North Falmouth and Hyannis. As a result of this crowding we shall be unable, in the summer of 1946, to take care of more than 375 investigators and students—that is, about 100 less than our pre-war average. Indeed, we can accommodate this number only because the authorities of the U. S. Fish and Wild Life Commission have granted us the use of a part of the Fisheries residence. For their cooperation in this, and in many other ways, the Laboratory is grateful.

When it is possible once more to build houses, some of this pressure for living space will be relieved. To encourage investigators to have homes here in Woods Hole, the Laboratory has opened up the Devil's Lane tract, situated a mile and more from the center of the village, between the State Road to Falmouth and the railroad. About 100 lots will presently be available.

In the meantime, the number of applicants for research space will undoubtedly increase, and we shall be unable to find places for all qualified investigators who wish to come. The Administration thus faces the unwelcome prospect of having to choose between applicants. The Executive Committee has ruled that investigators, instructors, and students should have preference over Library readers in the residences and at the Mess. But some further method of selection must be followed until the housing shortage is relieved.

4. Financial Problems

The report of the Treasurer shows that our financial condition is sound; that is, we are free from debt, and have about $57,000 in the Reserve and Current Cash accounts. But most of this has already been ear-marked to pay for the most necessary repairs, and for foreign journals not yet delivered. We shall still need a larger amount for other needed repairs and replacements. When these have been made we can say that our regular income from all sources is sufficient to maintain the Laboratory on its present basis. But in order to expand our research facilities we must have additional funds. It is estimated that $30,000 each year should be spent for this purpose.

5. Gifts

Mr. Allen R. Memhard has provided a fund of $1,000, the income of which may be awarded to a qualified student who has completed the Embryology course.

Mrs. Adele K. Stricker has presented to the Laboratory the sum of $50 in memory of her son, Capt. George J. Stricker, who worked here during the summers of 1933 and 1934.

Dr. A. C. Redfield contributed $100 for a hedge and trees to be planted to the east of the Stone Building.

Donations for current purposes received during the year were as follows: Mrs. E. B. Meigs, $25.00; Dr. William D. Curtis, $100.00; M. B. L. Associates, $630.00.

6. Deaths

This year we have sustained irreparable losses by death; Dr. T. H. Morgan, Trustee since 1897, whose scientific achievements and devotion to this Laboratory from its earliest days contributed greatly to its growth in usefulness and influence, and Dr. C. E. McClung, elected Trustee in 1913, active in all Laboratory affairs, especially in the building up of our great Library.

7. Election of Trustees

At the meeting of the Corporation, held August 14, 1945, the following were elected Trustees Emeriti: Dr. F. P. Knowlton, elected Trustee in 1922; Dr. R. S. Lillie, elected Trustee in 1921.

The following were elected Trustees: Dr. P. B. Armstrong, Professor of Anatomy, College of Medicine, Syracuse University; Dr. A. K. Parpart, Associate Professor of Biology, Princeton University.

8. Publications

The Executive Committee voted to print in this Report a list of papers, based wholly or in part on work done at this Laboratory, and published during the years 1941–1945. A similar list, which appeared in the Annual Report of 1908, covered the years from the beginning of the Laboratory in 1888 to 1907. It is hoped that eventually a complete compilation of titles to include the intervening years may be made.

Appended as parts of this Report are:

1. Publications from this Laboratory during the years 1941–1945.
2. The Staff.
3. Investigators and Students.
4. Tabular View of Attendance, 1941–1945.
5. Subscribing and Cooperating Institutions.
6. Evening Lectures.
7. Shorter Scientific Papers.
8. Members of the Corporation.

Respectfully submitted,
CHARLES PACKARD,
Director

1. PUBLICATIONS FROM THE MARINE BIOLOGICAL LABORATORY, 1941–1945

Note: An asterisk before a title indicates that the work was done only in part at this Laboratory.

ABELL, R. G. On the comparative permeability of blood capillary sprouts, newly formed capillaries, and older capillaries. *Anat. Rec.*, **82**: 1942.

ABELL, R. G. *See* also Zweifach, Abell, Chambers, and Clowes, 1945.

ABELL, R. G. AND I. H. PAGE. *Behavior of the arterioles in hypertensive rabbits and in normal rabbits following injections of angiotonin. *Biol. Bull.*, **81**: 1941 (abs.).

ABELL, R. G. AND I. H. PAGE. *The reaction of peripheral blood vessels to angiotonin, renin, and other pressor agents. *Jour. Exp. Med.*, **75**: 1942.

ADDISON, W. H. F. *The distribution of elastic tissue in the arterial pathway to the carotid bodies in the adult dog. *Biol. Bull.*, **81**: 1941 (abs.).

ADDISON, W. H. F. *Histologic methods adapted for rat tissues. A Chapter in "The Rat in Laboratory Investigation," Lippincott, 1942.

ADDISON, W. H. F. The hypophysis of the goose-fish. *Anat. Rec.*, **85**: 1943 (abs.).

ADDISON, W. H F. *The extent of the carotid pressoreceptor area in the cat as indicated by its special elastic-tissue wall. *Anat. Rec.*, **91**: 1945.

ADDISON, W. H. F. *The arterial relations of the glomus caroticum in the rabbit. *Anat. Rec.*, **88**: 1944 (abs.).

ALBAUM, H. G. AND BARRY COMMONER. The relation between the four-carbon acids and the growth of oat seedlings. *Biol. Bull.*, **80**: 1941.

ALLEE, W. C. *Integration of problems concerning protozoan populations with those of general biology. *Amer. Nat.*, **75**: 1941.

ALLEE, W. C. AND RUTH M. MERWIN. The effect of carbon dioxide on the rate of cleavage in frog's eggs. *Anat. Rec. Suppl.*, **81**: 1941 (abs.).

ALLEE, W. C. AND RUTH M. MERWIN. The effect of low concentration of carbon dioxide on the cleavage rate in frog's eggs. *Ecology*, **24**: 1943.

ALLEE, W. C., A. J. FINKEL AND H. R. GARNER. Factors affecting rate of cleavage in Arbacia; the accelerating action of copper. *Anat. Rec. Suppl.*, **81**: 1941 (abs.).

ALLEE, W. C., A. J. FINKEL AND H. R. GARNER. Copper and the acceleration of cleavage. *Jour. Cell. Comp. Physiol.*, **20**: 1942.

ALLEE, W. C., A. J. FINKEL, H. R. GARNER, R. M. MERWIN AND G. E. EVANS. Some effects of homotypic extracts on the rate of cleavage of Arbacia eggs. *Biol. Bull.*, **83**: 1942.

ALLEE, W. C. AND MARJORIE B. DOUGLIS. A dominance order in the hermit crab, Pagurus longicarpus Say. *Ecology*, **26**: 1945.

ALSUP, F. W. Photodynamic action in the eggs of Nereis limbata. *Jour. Cell. Comp. Physiol.*, **17**: 1941.

ALSUP, F. W. Photodynamic studies on Arbacia eggs. *Biol. Bull.*, **81**: 1941.

ALSUP, F. W. The effects of light alone and photodynamic action on relative viscosity of Amoeba protoplasm. *Physiol. Zool.*, **15**: 1942.

ANDERSON, T. F. *The study of colloids with the electron microscope. *Advances in Colloid Science*, **1**: 1942.

ANDERSON, T. F. *The application of the electron microscope to biology. *Collecting Net*, **17**: 1942.

ANDERSON, T. F. *See* also Harvey, E. B. and Anderson, 1943; Luria, Delbruck and Anderson, 1943; Richards, Steinbach and Anderson, 1943.

ANDERSON, T. F. AND A. G. RICHARDS. Nature through the electron microscope. *Scientific Month.*, **55**: 1942.

ANDREW, WARREN. The reticular nature of glia fibers in the cerebrum of the frog and in the higher vertebrates. *Jour. Comp. Neurol.*, **79**: 1943.

ANGERER, C. A. *See* also Hartman, Lewis, Brownell, Sheldon and Angerer. *Physiol. Zool.*, **17**: 1944.

ANGERER, C. A. AND H. ANGERER. *Weight variations of muscles of adrenalectomized frogs in normal and hypotonic Ringer solutions. *Amer. Jour. Physiol.*, **133**: 1941.

ANGERER, C. A. AND K. M. WILBUR. *The action of various types of electric fields on the relative viscosity of plasmagel of Amoeba proteus. *Physiol. Zool.*, **16**: 1943.

BAILEY, BASIL, P. KORAN AND H. C. BRADLEY. The autolysis of muscle of highly active and less active fish. *Biol. Bull.*, **83**: 1942.

BAKER, GLADYS E. *Studies in the genus Physalacria. *Bull. Torrey Bot. Club*, **68**: 1941.

BAKER, H. D. *Notes on Salasiella from Mexico. *Nautilus*, **54**: 1941.

BAKER, H. D. *Zonitid snails from Pacific Islands. *Bull. Bishop Museum, Honolulu*, **166**: 1941.

BAKER, H. D. *Some Haplotrematidae. *Nautilus*, **54**: 1941.

BAKER, H. D. *Puerto Rican Oleacinidae. *Nautilus*, **55**: 1941.

BAKER, H. D. *Outline of American Oleacininae and new species from Mexico. *Nautilus*, **55**: 1941.

BAKER, H. D. *A new genus of Mexican helicids. *Nautilus*, **56**: 1942.

BAKER, H. D. *A new genus of Chinese Microcystinae. *Nautilus*, **56**: 1942.

BAKER, H. D. *Some Antillean helicids. *Nautilus*, **56**: 1943.

BAKER, H. D. *The mainland genera of American Oleacininae. *Proc. Acad. Nat. Sci., Philadelphia*, **95**: 1943.

BAKER, R. F. *See* Cole and Baker, 1941.

BALL, E. G. A blue chromoprotein found in the eggs of the goose-barnacle. *Jour. Biol. Chem.*, **152**: 1944.

BALL, ERNEST. The effects of synthetic growth substances on the shoot apex of Tropaeolum majus. *Amer. Jour. Bot.*, **31**: 1944.

BALLARD, W. W. The mechanism for synchronous spawning in Hydractinia and Pennaria. *Biol. Bull.*, **82**: 1942.

BALLENTINE, ROBERT. *See* Parpart and Ballentine, 1943.

BARNES, W. A. AND O. B. FURTH. Roentgen rays in single and parabiotic mice. *Amer. Jour. Roentgenol. and Radium Therap.*, **69**: 1943.

BARRON, E. S. G. AND J. M. GOLDINGER. Pyruvate metabolism in fertilized and non-fertilized sea urchin eggs. *Biol. Bull.*, **81**: 1941.

BARTH, L. G. *Neural differentiation without organizer. *Jour. Exp. Zool.*, **87**: 1941.

BARTH, L. G. *Oxygen consumption of the amphibian gastrula. *Physiol. Zool.*, **15**: 1942.

BARTH, L. G. *Colloid chemistry of development. A chapter in Alexander's Colloid Chemistry. New York, 1944.

BARTH, L. G. The determination of the regenerating hydranth in Tubularia. *Physiol. Zool.*, **17**: 1944.

BARTH, L. G. *See* also Goldin and Barth, 1941.

BARTLETT, J. H. *Transient Anode Phenomena. *Trans. Electrochem. Soc.*, **87**: 1945.

BARTLETT, J. H. *Periodic phenomena at anodes. *Phys. Rev.*, **67**: 1945.

BEAMS, H. W. *See* Evans, Beams and Smith, 1941.

BEERS, C. D. The role of bacteria in the excystment of the ciliate Didinium nasutum. *Biol. Bull.*, **89**: 1945 (abs.).

BELDA, W. H. *Permeability to water in Pelomyxa carolinensis. 1. Changes in volume of P. carolinensis in solutions of different osmotic concentration. *The Salesianum*, **37**: 1942.

BELDA, W. H. 2. The contractile vacuoles of P. carolinensis. *The Salesianum*, **37**: 1942.

BELDA, W. H. 3. The permeability constant for water in P. caroliensis. *The Salesianum*, **38**: 1943.

BERGER, C. A. *Some criteria for judging the degree of polyploidy of cells in the resting stage. *Amer. Nat.*, **75**: 1941.

BERGER, C. A. *Reinvestigation of polysomaty in Spinacia. *Bot. Gaz.*, **102**: 1941.

BERGER, C. A. *Multiple chromosome complexes in animals and polysomaty in plants. *Cold Spring Harbor Symposia*, **9**: 1941.

BERGER, C. A. *Experimental studies on the cytology of Allium. *Torreya* (abs.) **44**: 1944.

BERGER, C. A. AND E. R. WITKUS. *A cytological study of c-mitosis in the polysomatic plant Spinacia oleracea, with comparative observations on Allium cepa. *Bull. Torrey. Bot. Club*, **70**: 1943.

BERGER, C. A. AND E. R. WITKUS. *Veratrine, a new polyploidy inducing agent. *Jour. Hered.*, **35**: 1944.

BERGER, C. A., E. R. WITKUS AND B. J. SULLIVAN. *The cytological effects of benzene vapor. *Bull. Torrey Bot. Club*, **71**: 1944.

BERTHOLF, L. M. Accelerating metamorphosis in the tunicate, Styela partita. *Biol. Bull.*, **89**: 1945 (abs.).

BERTHOLF, L. M. AND S. O. MAST. Metamorphosis in the larva of the tunicate, Styela partita. *Biol. Bull.*, **87**: 1944 (abs.).

BEVELANDER, GERRIT. *Radioactive phosphate absorption by dentin and enamel. *Jour. Dent. Res.*, **24**: 1945.

BEVELANDER, GERRIT. *The histochemical localization of alkaline phosphatase in the developing tooth. *Jour. Cell. Comp. Physiol.*, **26**: 1945.

BEVELANDER, GERRIT. *The localization of phosphatase in the cyclic growth of the hair. *Anat. Rec.*, **91**: 1945.

BIRMINGHAM, LLOYD. Regeneration in the early zooid of Amaroucium constellatum. *Biol. Bull.*, **81**: 1941 (abs.).

BLISS, A. F. Derived photosensitive pigments from invertebrate eyes. *Jour. Gen. Physiol.*, **26**: 1943.

BOCHE, R. D. AND J. B. BUCK. Studies on the hydrogen ion concentration of insect blood and their bearing on *in vitro* cytological technique. *Physiol. Zool.*, **15**: 1942.

BODIAN, DAVID. *Cytological aspects of synaptic function. *Physiol. Rev.*, **22**: 1942.

BODIAN, DAVID. *Poliomyelitic changes in multinucleated neurons, with special reference to the site of action of virus in the cell. *Bull. Johns Hopkins Hosp.*, **77**: 1945.

Bodian, David and R. C. Mellors. *The regenerative cycle of motor neurons, with special reference to phosphatase activity. *Jour. Exp. Med.*, **81**: 1945.

Boell, E. J. and L. L. Woodruff. Respiratory metabolism and mating types in Paramoecium calkinsi. *Jour. Exper. Zool.*, **87**: 1941.

Botsford, E. Frances. The effect of physostigmine on the responses of earthworm body wall preparations to successive stimuli. *Biol. Bull.*, **80**: 1941.

Bradley, H. C. *See* Bailey, Koran and Bradley, 1942.

Brooks, M. M. *Infrared spectrophotometric studies on hemoglobin as affected by cyanide, methylene blue, and carbon monoxide. *Amer. Jour. Physiol.*, **132**: 1941.

Brooks, M. M. Effects of CO and methylene blue upon O_2 consumption of shark blood. *Proc. Soc. Exp. Biol. Med.*, **46**: 1941.

Brooks, M. M. Interpretations of effects of CO and CN on oxidations in living cells. *Collecting Net*, **16**: 1941.

Brooks, M. M. Further interpretations of the effects of CO and CN on oxidations in living cells. *Biol. Bull.*, **81**: 1941.

Brooks, M. M. The effect of thiamine chloride on the oxygen consumption and the development of Arbacia punctulata at different stages. *Biol. Bull.*, **83**: 1942.

Brooks, M. M. Mechanism of fertilization of eggs. *Federation Proc.*, **2**: 1943.

Brooks, M. M. Methylene blue, potassium cyanide, and carbon monoxide as indicators for studying the oxidation-reduction potentials of developing marine eggs. *Biol. Bull.*, **84**: 1943.

Brooks, M. M. *El mecanismo de accion del azul de metileno en las celulas vivas. *Actas Acad. Nacional de Ciensa exactas, fisicas y natuales de Lima, Peru*, **7**: 1944.

Brooks, M. M. *The effect of methylene blue on performance efficiency at high altitudes. *Jour. Aviation Med.*, **16**: 1945.

Brooks, M. M. *Oxidation-reduction studies on Penicillium notatum and other organisms. *Biol. Bull.*, **89**: 1945.

Brooks, M. M. Electrode potential measurements of Penicillium notatum. *Federation Proc.*, **4**: 1945.

Brooks, M. M. Mechanism of fertilization of eggs. *Federation Proc.*, **5**: 1945.

Brooks, M. M. and S. C. Brooks. *Permeability of Living Cells. Gebrüder Borntraeger, Berlin. Preprinted by Edwards Bros., 1945.

Brooks, S. C. Intake and loss of phosphate ions by eggs and larvae of Arbacia and Asterias. *Biol. Bull.*, **83**: 1942.

Brooks, S. C. Intake and loss of ions by living cells. 1. Eggs and larvae of Arbacia punctulata and Asterias forbesi exposed to phosphate and sodium ions. *Biol. Bull.*, **84**: 1943.

Brooks, S. C. 2. Early changes of phosphate content of Fundulus eggs. *Biol. Bull.*, **84**: 1943.

Brooks, S. C. *The permeability of cells. *Science*, **100**: 1944.

Brooks, S. C. *See* also Brooks and Brooks, 1945.

Brown, D. E. S. *See* Marsland and Brown, 1941, 1942; Marsland, Johnson and Brown, 1941, 1942; Hiatt, Brown, Quinn and MacDuffie, 1945.

Brown, F. A. and O. Cunningham. Upon the presence and distribution of a chromatophorotropic principle in the central nervous system of Limulus. *Biol. Bull.*, **81**: 1941.

Brown, F. A. and V. J. Wulff. Chromatophore types in Crago and their endocrine control. *Jour. Cell. Comp. Physiol.*, **18**: 1941.

Brownell, K. A. *See* Hartman, Lewis, Brownell, Shelden and Walther, 1941; Hartman, Lewis, Brownell, Angerer and Shelden, 1944.

Buchsbaum, Ralph and R. Williamson. The rate of elongation and constriction of dividing sea urchin eggs as a test of a mathematical theory of cell division. *Physiol. Zool.*, **16**: 1943.

Buck, J. B. *Micromanipulation of salivary gland chromosomes. *Jour. Hered.*, **33**: 1942.

Buck, J. B. *See* also Boche and Buck, 1942.

Buck, J. B. and A. M. Melland. *Methods for isolating, collecting, and orienting salivary gland chromosomes for diffraction analysis. *Jour. Hered.*, **33**: 1942.

Budington, R. A. The ciliary transport-system of Asterias forbesii. *Biol. Bull.*, **83**: 1942.

Bullock, T. H. Neuromuscular facilitation in scyphomedusae. *Jour. Cell. Comp. Physiol.*, **22**: 1943.

Bullock, T. H. The giant nerve fiber system in balanoglossids. *Jour. Comp. Neurol.*, **80**: 1944.

BULLOCK, T. H. Problems in the comparative study of brain waves. *Yale Jour. Biol. Med.*, **17**: 1945.

BULLOCK, T. H. Organization of the giant nerve fiber system in Neanthes virens. *Biol. Bull.*, **89**: 1945.

BULLOCK, T. H. Anatomical organization of the nervous system of Enteropneusta. *Quart. Jour. Micr. Sci.*, **86**: 1945.

BULLOCK, T. H. AND D. NACHMANSOHN. Choline esterase in primitive nervous systems. *Jour. Cell. Comp. Physiol.*, **20**: 1942.

CABLE, R. M. *See* also Hunninen and Cable, 1941, 1943.

CABLE, R. M. AND A. V. HUNNINEN. Studies on Deropristis inflata, its life history and affinities to trematodes of the family Acanthocolpidae. *Biol. Bull.*, **82**: 1942.

CABLE, R. M. AND A. V. HUNNINEN. Studies on the life history of Siphodera vinaledwardsii. *Jour. Parasitol.*, **28**: 1942.

CAHEN, R. L. *The effects of morphine on the cortical activity of the rat. *Yale Jour. Biol. Med.*, **16**: 1944.

CAHEN, R. L. *The influence of morphine on tissue permeability and the spreading effect of hyaluronidase. *Yale Jour. Biol. Med.*, **16**: 1944.

CAHEN, R. L. *Urinary 17 ketosteroids in metabolism. 1. Standardized chemical estimation. *Jour. Biol. Chem.*, **152**: 1944.

CANNAN, R. K. *The hydrogen ion dissociation curve of beta-lactoglobulin. *Jour. Biol. Chem.*, **142**: 1942.

CANNAN, R. K. *The dicarboxylic amino acids in protein hydrolysates. *Jour. Biol. Chem.*, **152**: 1944.

CARSON, H. L. A comparative study of the apical cell of the insect testis. *Jour. Morph.*, **77**: 1945.

CHAMBERS, ROBERT. The intrinsic expansibility of the fertilization membrane of echinoderm ova. *Jour. Cell. Comp. Physiol.*, **19**: 1942.

CHAMBERS, ROBERT. Electrolytic solutions compatible with the maintenance of protoplasmic structures. *Biol. Symposia*, **10**: 1943.

CHAMBERS, ROBERT. Post war Biology rehabilitation. *Science*, **100**: 1944.

CHAMBERS, ROBERT. Some physical properties of protoplasm. Chapter in Alexander's Colloid Chemistry, 1944.

CHAMBERS, ROBERT. *Rehabilitation of the biological sciences in the post-war period. *Am. Nat.*, **79**: 1945.

CHAMBERS, ROBERT, B. W. ZWEIFACH, B. E. LOWENSTEIN AND R. E. LEE. Vaso-excitor and vaso-depressor substances as "toxic" factors in experimentally induced shock. *Proc. Soc. Exp. Biol. Med.*, **56**: 1944.

CHAMBERS, ROBERT, B. W. ZWEIFACH AND B. E. LOWENSTEIN. *Circulatory reactions of rats, traumatized in the Noble-Collip drum. *Am. J. Physiol.*, **139**: 1943.

CHAMBERS, ROBERT, B. W. ZWEIFACH AND B. E. LOWENSTEIN. *The peripheral circulation during the tourniquet syndrome in the rat. *Ann. Surg.*, **120**: 1944.

CHASE, A. M. *Effect of azide on Cypridina luciferin. *Collecting Net*, **16**: 1941.

CHASE, A. M. Observations on luminescence in Mnemiopsis. *Biol. Bull.* **81**: 1941 (abs.).

CHASE, A. M. *The reaction of Cypridina luciferin with azide. *Jour. Cell Comp. Physiol.*, **19**: 1942.

CHASE, A. M. *The absorption spectrum of luciferin and oxidized luciferin. *Jour. Biol. Chem.*, **150**: 1943.

CHASE, A. M. *The visible absorption band of reduced luciferin. *Jour. Biol. Chem.*, **159**: 1945.

CHENEY, R. H. Myofibrillar modifications induced by caffeine in cardiac muscle of the frog. *Jour. Comp. Physiol.*, **18**: 1941.

CHENEY, R. H. Caffeine effect in fertilization and development of Arbacia eggs. *Biol. Bull.*, **83**: 1942 (abs.).

CHENEY, R. H. Oxygen consumption of caffeinized Arbacia eggs. *Biol. Bull.*, **83**: 1942. (abs.).

CHENEY, R. H. Development of Arbacia eggs in caffeinized sea water. *Anat. Rec.*, **84**: 1942 (abs.).

CHENEY, R. H. Inhibitory effect of caffeine on oxygen consumption in Arbacia eggs. *Anat. Rec.*, **84**: 1942 (abs.).

CHENEY, R. H. *Variation in reproductive phenomena by caffeine. *Federation Proc.*, **3**: 1944 (abs.).

CHENEY, R. H. The effects of caffeine on oxygen consumption and cell division in the fertilized egg of the sea urchin. *Jour. Gen. Physiol.*, **29**: 1945.

CHURNEY, LEON. The osmotic properties of the nucleus. *Biol. Bull.*, **82**: 1942.

CLAFF, C. L. *Glass electrode for determination of hydrogen ion activity of small quantities of culture media. *Science*, **94**: 1941.

CLAFF, C. L., VIRGINA C. DEWEY AND G. W. KIDDER. *Feeding mechanisms in three species of Bresslaua. *Biol. Bull.*, **81**: 1941.

CLAFF, C. L. AND O. SWENSON. *Micro glass electrode technique for determination of hydrogen-ion activity of blood and other biological fluids. *Jour. Biol. Chem.*, **152**: 1944.

CLARK, E. R. AND ELEANOR L. CLARK. *Microscopic observations on the formation of cartilage and bone in the living mammal. *Amer. Jour. Anat.*, **70**: 1942.

CLARK, E. R. AND ELEANOR L. CLARK. *Caliber changes in minute blood vessels observed in living mammal. *Amer. Jour. Anat.*, **73**: 1943.

CLARK, E. R. AND ELEANOR L. CLARK *The formation of venae comites. *Anat. Rec.*, **85**: 1943.

CLARK, E. R. AND ELEANOR L. CLARK. *Growth and behavior of epidermis as observed microscopically in the living, in chambers introduced in the rabbit's ear. *Anat. Rec.*, **88**: 1944.

CLOWES, G. H. A. *Interactions of biologically significant substances in surface films, with especial reference to two-dimensional solutions and association complexes formed by carcinogenic hydrocarbons and sterols. *Publication 21. Amer. Assoc. Advance. Sci.*, 1942.

CLOWES, G. H. A. *See* also Krahl, Keltch, Neubeck and Clowes, 1941; Keltch, Baker, Krahl and Clowes, 1941; Davis, Baker and Clowes, 1941, 1942; Krahl, Jandorff and Clowes, 1942; Powell, Krahl and Clowes, 1942; Hutchens, Keltch, Krahl and Clowes, 1942; Zweifach, Abell, Chambers and Clowes, 1945.

COLE, K. S. Rectification and inductance in the squid giant axon. *Jour. Gen. Physiol.*, **25**: 1941.

COLE, K. S. *See* also Guttman and Cole, 1941; Curtis and Cole, 1942, 1944.

COLE, K. S. AND R. F. BAKER. Transverse impedance of the squid giant axon during current flow. *Jour. Gen. Physiol.*, **24**: 1941.

COLE, K. S. AND R. F. BAKER. Longitudinal impedance of the squid giant axon. *Jour. Gen. Physiol.*, **24**: 1941.

COLE, K. S. AND H. J. CURTIS. Membrane potential of the squid giant axon during current flow. *Jour. Gen. Physiol.*, **24**: 1941.

COLE, K. S. AND H. J. CURTIS. *Electrical Physiology: Electrical resistance and impedance of cells and tissues. Chapter in Medical Physics. Chicago, 1944.

COLE, K. S. AND R. H. COLE. *Dispersion and absorption in dielectrics. 1. Alternating current characteristics. *Jour. Chem. Phys.*, **2**: 1941.

COLE, K. S. AND R. H. COLE. *2. Direct current characteristics. *Jour. Chem. Phys.* **10**: 1942.

COLWIN, LAURA H. Binary fission and conjugation in Urceolaria synapta, with special reference to the nuclear phenomena. *Jour. Morph.*, **75**: 1944.

COMMONER, BARRY. *See* Albaum and Commoner, 1941.

CORNMAN, IVOR. Characteristics of the acceleration of Arbacia cleavage in hypotonic sea-water. *Biol. Bull.* **81**: 1941 (abs.).

CORNMAN, IVOR. Sperm activation by Arbacia egg extractives, with special reference to echinochrome. *Biol. Bull.* **80**: 1941.

CORNMAN, IVOR. Acceleration of cleavage of Arbacia eggs by hypotonic sea water. *Biol. Bull.*, **84**: 1943.

COSTELLO, D. P. *Advances in Zoology during 1940. *Ind. Engineer. Chem.*, **19**: 1941.

COSTELLO, D. P. Segregation of ooplasmic constituents. *Jour. Elisha Mitchell Sci. Soc.*, **61**: 1945.

COSTELLO, D. P. Experimental studies in germinal localization in Nereis. 1. The development of isolated blastomeres. *Jour. Exp. Zool.*, **100**: 1945.

COSTELLO, D. P. WITH G. I. LAVIN. Ultra violet photomicroscopy of the Nereis and Asterias egg. *Anat. Rec. Suppl.*, **87**: 1943. (abs.).

CROUSE, HELEN V. *Translocations in Sciara; their bearing on chromosome behavior and sex determination. *Univ. Missouri Res. Bull.*, **379**: 1943.

CROUSE, HELEN V. *See* also Ris and Crouse, 1945.

CROWELL, SEARS. A comparison of shells utilized by Hydractinia and Podocoryne. *Ecology*, **26**: 1945.

CUNNINGHAM, O. *See* Brown and Cunningham, 1941.

CURTIS, H. J. *See* also Cole and Curtis, 1941.

CURTIS, H. J. AND K. S. COLE. Membrane resting and action potentials from the squid giant axon. *Jour. Cell. Comp. Physiol.*, **19**: 1942.

DAVSON, HUGH. *See* also Shapiro and Davson, 1941.

DAVSON, HUGH AND J. M. REINER. Ionic permeability; an enzyme-like factor concerned in the migration of sodium through the cat erythrocyte membrane. *Jour. Cell. Comp. Physiol.*, **20**: 1942.

DELBRUCK, M. *See* Luria, Delbruck and Anderson, 1943.

DENT, J. N. *The embryonic development of Plethodon cinereus as correlated with the differentiation and functioning of the thyroid gland. *Jour. Morph.* **71**: 1942.

DENT, J. N. *See* also Lynn and Dent, 1941.

DEWEY, VIRGINIA C. *See* also Claff, Dewey and Kidder, 1941.

DEWEY, VIRGINIA C. AND G. W. KIDDER. The possibility of thiamin synthesis by ciliates. *Biol. Bull.*, **81**: 1941. (abs.).

DOUGLIS, MARJORIE B. *See* Allee and Douglis, 1945.

DZIEMIAN, A. J. *The permeability and the lipid content of immature red cells. *Jour. Cell. Comp. Physiol.*, **20**: 1942.

EVANS, T. C., H. W. BEAMS, AND M. E. SMITH. Effects of roentgen radiation on the jelly of the Arbacia egg. *Biol. Bull.* **80**: 1941.

EVANS, T. C. AND J. C. SLAUGHTER. Effect of sea water on the radiosensitivity of Arbacia sperm. *Biol. Bull.*, **81**: 1941 (abs.).

EVANS, T. C. AND J. C. SLAUGHTER, E. P. LITTLE AND G. FAILLA. Influence of the medium on radiation injury of sperm. *Radiology*, **39**: 1942.

FAILLA, G. *See* Evans, Slaughter, Little and Failla, 1942.

FAUST, E. C. *Clinical Parasitology. Co-author with C. F. Craig, Lea and Febiger, 1945.

FINKEL, A. J. *See* Allee, Finkel and Garner, 1941, 1942; Allee, Finkel, Garner, Merwin and Evans, 1942

FISHER, K. C. The fractionation of cellular respiration by the use of narcotics. *Biol. Bull.*, **81**: 1941 (abs.).

FREEDMAN, W. B. AND R. WALKER. *Size, development, and innervation of labyrinth sensory areas in Squalus. *Jour. Comp. Neur.*, **77**: 1942.

FREIS, E. F. B. Some neurohumoral evidence for double innervation of xanthophores in killfish. *Biol. Bull.*, **82**: 1942.

FRISCH, J. A. *The rate of pulsation of the posterior contractile vacuole in Paramoecium woodruffi and P. calkinsi. *Anat. Rec.* **89**: 1944 (abs.).

FRISCH, J. A. *The rate of adaptation of P. caudatum to sea water. *Anat. Rec.* **89**: 1944 (abs.).

FROEHLICH, ALFRED. The influence of drugs on heat narcosis. *Biol. Bull.* **89**: 1945 (abs.).

FURTH, JACOB. *The teaching of experimental pathology. *Arch. Path.*, **34**: 1942.

FURTH, JACOB. Neoplastic growth. *Ann. Rev. Physiol.*, **6**: 1944.

FURTH, JACOB, R. K. COLE AND M. C. BOON. *The effect of maternal influence upon spontaneous leukemia of mice. *Cancer Research*, **2**: 1942.

FURTH, JACOB AND M. C. BOON. *Enhancement of leukemogenic action of methylcholanthrene by pre-irradiation with X-rays. *Science*, **98**: 1943.

FURTH, JACOB, M. C. BOON AND N. KALISS. *On the genetic character of neoplastic cells as determined in transplantation experiments: with notes on the somatic mutation theory. *Cancer Research*, **4**: 1944.

GABRIEL, M. L. The effect of temperature on vertebral variations is Fundulus. *Biol. Bull.*, **83**: 1942 (abs.).

GABRIEL, M. L. Factors affecting the number and form of vertebrae in Fundulus. *Jour. Exp. Zool.*, **95**: 1944.

GALTSOFF, P. S. Storage and distribution of manganese in Ostrea virginica. *Collecting Net*, **16**: 1941.

GALTSOFF, P. S. Accumulation of manganese and the sexual cycle in Ostrea virginica. *Physiol. Zool.*, **15**: 1942.

GALTSOFF, P. S. Reaction of the oyster to free chlorine. *Biol. Bull.*, **89**: 1945 (abs.).

GARNER, H. R. *See* Allee, Finkel and Garner, 1941, 1942.

GARREY, W. E. Action of acetylcholine on the heart of Limulus. *Amer. Jour. Physiol.*, **133**: 1941.

GARREY, W. E. An analysis of the action of acetylcholine on the cardiac ganglion of Limulus. *Amer. Jour. Physiol.* **136**: 1942.
GATES, R. R. Tests of nuceoli and cytoplasmic granules in marine eggs. *Biol. Bull.*, **81**: 1941.
GATES, R. R. *Nucleoli and phylogeny. *Collecting Net*, **17**: 1942.
GATES, R. R. *Chromosome numbers in mammals and man. *Science*, **96**: 1942.
GATES, R. R. *Symbols for human genes. *Science*, **95**: 1942.
GATES, R. R. *Nucleoli and related nuclear structures. *Bot. Rev.*, **8**: 1942.
GATES, R. R. *Our ancestors, ourselves, our descendants. *Medical Genetics and Eugenics*, **2**: 1943.
GATES, R. R. (with G. N. PATHAK). *Variations in the offspring of tetraploid Oenotheras. *Amer. Naturalist*, **78**: 1944.
GIDGE, NATALIE M. AND S. M. ROSE. The role of larval skin in promoting limb regeneration in adult Anura. *Jour. Exp. Zool.*, **97**: 1944.
GIESE, A. C. *Studies on nutrition of dim and bright variants of a species of luminous bacteria. *Jour. Bact.*, **46**: 1943.
GIESE, A. C. *The action of azide on luminescence, respiration, and growth of the luminous bacteria. *Jour. Cell. Comp. Physiol.*, **26**: 1945.
GIESE, A. C. *Ultraviolet radiations and life. *Physiol. Zool.*, **18**: 1945.
GIESE, A. C. *Effects of ultraviolet radiations on luminescence and respiration of Achromobacter fischeri. *Jour. Cell. Comp. Physiol.*, **17**: 1941.
GIESE, A. C. AND E. L. TATUM. *The effect of some vitamins of the B-complex on respiration of mutants of Neurospora. *Biol. Bull.*, **83**: 1942 (abs.).
GILBERT, P. W. *The urogenital system of the male frilled shark, Chlamydoselachus anguineus. *Anat. Rec.*, **84**: 1942 (abs.).
GILBERT, P. W. *The morphology of the male urogenital system of the frilled shark Chlamydoselachus anguineus. *Jour. Morph.*, **3**: 1943.
GILMAN, L. C. *Mating types in diverse races of Paramoecium caudatum. *Biol. Bull.*, **80**: 1941.
GLASER, O. C. Protein metabolism and embryonic growth rate. *Biol. Bull.*, **83**: 1942 (abs.).
GOLDIN, A. Factors influencing regeneration and polarity determination in Tubularia crocea. *Biol. Bull.*, **82**: 1942.
GOLDIN, A. A quantitative study of the interrelationships of oxygen and hydrogen ion concentration in influencing Tubularia regeneration. *Biol. Bull.*, **82**: 1942.
GOLDIN, A. *See* also Spiegelman and Goldin, 1944.
GOLDIN, A. AND L. G. BARTH. Regeneration of coenosarc fragments removed from the stem of Tubularia crocea. *Biol. Bull.*, **81**: 1941.
GOLDINGER, J. M. *See* Barron and Goldinger, 1941.
GOODCHILD, CHAUNCEY. *Additional observations on the life history of Gorgodera amplicava. *Jour. Parasitol.*, **31**: 1945.
GOODRICH, H. B., N. D. JOSEPHSON, J. P. TRINKHAUS AND JEANNE M. SLATE. *The cellular expression and genetics of two new genes in Lebistes reticulatus. *Genetics*, **29**: 1944.
GRANICK, SAM. *See* Michaelis and Granick, 1945.
GRAVE, B. H. The sexual cycle of the shipworm, Teredo navalis. *Biol. Bull.*, **82**: 1942 (abs.).
GRAVE, CASWELL. Further studies of metamorphosis of ascidian larvae. *Biol. Bull.*, **81**: 1941 (abs.).
GRAVE, CASWELL. The "eye spot" and light response of the larva of Cynthia partita. *Biol. Bull.*, **81**: 1941 (abs.).
GRAVE, CASWELL, AND S. O. MAST. The larva of Styela (Cynthia) partita; structure, activities, and duration of life. *Jour. Morph.*, **75**: 1944.
GRAY, I. E. *Changes in weight and water content during the life cycle of the wood-eating beetle, Passalus cornutus. *Biol. Bull.*, **86**: 1944.
GROSCH, D. S. *The relation of cell size and organ size to mortality in Habrobracon. *Growth*, **9**: 1945.
GUTTMAN, RITA. *Action of potassium and narcotics on rectification in nerve and muscle. *Jour. Gen. Physiol*, **28**: 1944.
GUTTMAN, RITA AND K. S. COLE. The rectifying property of the giant axon of the squid. *Collecting Net*, **16**: 1941.
GUTTMAN, RITA AND K. S. COLE. Electrical rectification in single nerve fibers. *Proc. Soc. Exp. Biol. Med.*, **48**: 1941.

HAGER, R. P. *Sex linkage of stubby in Habrobracon. *Biol. Bull.*, **81**: 1941 (abs.).

HAMILTON, H. L. *The influence of hormones on the differentiation of melanophores in birds. *Biol. Bull.*, **81**: 1941 (abs.).

HAMILTON, H. L. AND B. H. WILLIER. *Developmental Physiology. *Ann. Rev. Physiol.*, **4**: 1942.

HARNLY, M. H. *Wing form and gene function in nine genotypes of Drosophila melanogaster. *Biol. Bull.*, **82**: 1942.

HARRIS, D. L. The osmotic properties of cytoplasmic granules of the sea urchin egg. *Biol. Bull.*, **85**: 1943.

HARTMAN, F. A., L. A. LEWIS, K. A. BROWNELL, F. F. SHELDEN AND R. F. WALTHER. Some blood constituents of the normal skate. *Physiol. Zool.* **14**: 1941.

HARTMAN, F. A., F. F. SHELDEN, AND E. L. GREEN. Weights of interrenal glands of elasmobranchs. *Anat. Rec.*, **87**: 1943.

HARTMAN, F. A., L. A. LEWIS, K. A. BROWNELL, C. A. ANGERER AND F. F. SHELDEN. Effect of interrenalectomy on some blood constituents in the skate. *Physiol. Zool.*, **17**: 1944.

HARVEY, ETHEL BROWNE. Relation of the size of "halves" of the Arbacia punctulata egg to centrifugal force. *Biol. Bull.*, **80**: 1941.

HARVEY ETHEL BROWNE. The cytology of fertilization and cleavage of Arbacia punctulata. *Turtox News*, **19**: 1941.

HARVEY ETHEL BROWNE. Cross fertilization of echinoderms. *Science*, **94**: 1941.

HARVEY ETHEL BROWNE. Vital staining of the centrifuged Arbacia egg. *Biol. Bull.*, **81**: 1941.

HARVEY ETHEL BROWNE. Maternal inheritance in echinoderm hybrids. *Biol. Bull.*, **81**: 1941. (abs.).

HARVEY ETHEL BROWNE. Rate of breaking and size of the "halves" of the Arbacia egg when centrigued in hypo- and hypertonic sea water. *Biol. Bull.*, **85**: 1943.

HARVEY, ETHEL BROWNE. *Early biological photomicrographs. *Jour. Biol. Photograph. Assoc.*, **13**: 1945.

HARVEY ETHEL BROWNE. Stratification and breaking of the Arbacia egg when centrifuged in single salt solutions. *Biol. Bull.*, **89**: 1945.

HARVEY ETHEL BROWNE. Development of granule-free fractions of Arbacia eggs. *Biol. Bull.*, **89**: 1945 (abs.).

HARVEY ETHEL BROWNE AND T. F. ANDERSON. The spermatozoan and fertilization membrane of Arbacia, as shown by the electron microscope. *Biol. Bull.*, **85**: 1943.

HARVEY ETHEL BROWNE AND G. I. LAVIN. The chromatin in the living Arbacia egg; and the cytoplasm of the centrifuged egg as photographed by ultraviolet light. *Biol. Bull.*, **86**: 1944.

HARVEY, E. N. Stimulation of cells by intense flashes of ultraviolet light. *Jour. Gen. Physiol.*, **25**: 1942.

HARVEY, E. N. Note on the red luminescence and the red pigment of the "railroad worm." *Jour. Cell. Comp. Physiol.*, **25**: 1945.

HARVEY, E. N. AND H. SHAPIRO. The recovery period (relaxation) of marine eggs after deformation. *Jour. Cell. Comp. Physiol.*, **17**: 1941.

HARVEY, E. N. AND F. J. M. SICHEL. The response of single striated muscle fibers to intense flashes of ultraviolet light. *Jour. Cell. Comp. Physiol.*, **19**: 1942.

HARVEY, E. N. AND F. J. M. SICHEL. A method of recording the dimensions of muscle fiber striations during contraction. *Federation Proc.*, **1**: 1942.

HARVEY, E. N. AND F. J. M. SICHEL. High speed linear photography. *Jour. Cell. Comp. Physiol.*, **25**: 1945.

HARVEY, E. N., D. K. BARNES, W. D. MCELROY, A. H. WHLTELY, D. C. PEASE AND K. W. COOPER. *Bubble formation in animals. I. Physical factors. *Jour. Cell. Comp. Physiol.*, **24**: 1944.

HASSETT, C. C. *Photodynamic action in the flagellate Peranema trichophorum with special reference to motor response to light. *Physiol. Zool.*, **17**: 1944.

HAYASHI, TERU. Dilution medium and survival of the spermatozoa of Arbacia punctulata. I. Effect of the medium on fertilizing power. *Biol. Bull.*, **89**: 1945.

HAYWOOD, CHARLOTTE. The permeability of the toadfish liver to inulin, with and without choleretics. *Federation Proc.*, **2**: 1943 (abs.).

HAYWOOD, CHARLOTTE, VIRGINIA C. DICKERSON, AND MARGARET C. COLLINS. *The secretion of dye by the fish liver. *Jour. Cell. Comp. Physiol.*, **25**: 1945.

HEILBRUNN, L. V. *An Outline of General Physiology. 2nd Ed. Saunders. 1943.
HEWATT, W. G. A method of narcotizing Holothurians. *Science*, **97**: 1943.
HIATT, E. P. AND G. P. QUINN. *The distribution of quinine, quinidine, cinchonine, and cinchonidine in fluids and tissues of dogs. *Jour. Pharmacol. Exp. Therap.*, **83**: 1945.
HIATT, E. P., D. E. S. BROWN, G. P. QUINN AND K. MACDUFFIE. *The blocking action of the cinchona alkaloids and certain related compounds on the cardioinhibitory vagus endings of the dog. *Jour. Pharmacol. Exp. Therap.*, **85**: 1945.
HIBBARD, HOPE AND G. I. LAVIN. *A study of the Golgi apparatus in chicken gizzard epithelium by means of the quartz microscope. *Biol. Bull.*, **89**: 1945.
HIESTAND, W. A. Oxygen consumption of the sea cucumber as a function of oxygen tension and hydrogen ion concentration of the surrounding medium. *Trans. Wisconsin Acad. Sciences, Arts and Letters*, **32**: 1941.
HIESTAND, W. A. Action of certain drugs on the sea star, Asterias forbesii. *Proc. Soc. Exp. Biol. Med.*, **52**: 1943.
HILL, S. E. The relation between protoplasmic streaming and the action potential in Nitella and Chara. *Biol. Bull.*, **81**: 1941 (abs.).
HOLLINGSWORTH, JOSEPHINE. Activation of Cumingia and Arbacia eggs by bivalent cations. *Biol. Bull.*, **81**: 1941.
HOPKINS, D. L. *See* Mast and Hopkins, 1941.
HORN, ANNABELLE. *Proof for multiple allelism of sex differentiating factors in Habrobracon. *Amer. Nat.*, **77**: 1943.
HOUCK, C. R. The effects of bichloride of mercury upon the luminescence and respiration of the luminous bacterium, Achromobacter fischeri. *Jour. Cell. Comp. Physiol.*, **20**: 1942.
HUNNINEN, A. V. *See* also Cable and Hunninen, 1941, 1942.
HUNNINEN, A. V. AND R. M. CABLE. Life history of Lecithaster confusus. *Jour. Parasitol.*, **29**: 1943.
HUNNINEN, A. V. AND R. M. CABLE. The life history of Podocotyle atomon. *Trans. Amer. Microscop. Soc.*, **62**: 1943.
HUTCHENS, J. O. The utilization of ammonia by Chilomonas paramoecium. *Biol. Bull.*, **81**: 1941 (abs.).
HUTCHENS, J. O., A. K. KELTCH, M. E. KRAHL AND G. H. A. CLOWES. Studies on cell metabolism and cell division. VI. Observations on the glycogen content, carbohydrate consumption, lactic acid production, and ammonia production of eggs of Arbacia punctulata. *Jour. Gen. Physiol.*, **25**: 1942.
HUTCHENS, J. O., M. J. KOPAC AND M. E. KRAHL. The cytochrome content of centrifugally separated fractions of unfertilized Arbacia eggs. *Jour. Cell. Comp. Physiol.*, **20**: 1942.
IRVING, LAURENCE. *See* Root and Irving, 1941.
JACOBS, M. H. *See* also Netzky and Jacobs, 1941; Stewart and Jacobs, 1941.
JACOBS, M. H. AND DOROTHY R. STEWART. Catalysis of ionic exchange by bicarbonates. *Biol. Bull.*, **81**: 1941.
JACOBS, M. H. AND DOROTHY R. STEWART. The role of carbonic anhydrase in certain exchange involving the erythrocyte. *Jour. Gen. Physiol.*, **25**: 1942.
JACOBS, M. H. AND DOROTHY R. STEWART. *A biological method for the quantitative estimation of certain organic bases. *Amer. Jour. Med. Sci.*, **206**: 1943.
JACOBS, M. H. AND DOROTHY R. STEWART. *Osmotic equilibria between the erythrocyte and a complex external solution. *Amer. Jour. Med. Sci.*, **209**: 1945.
JACOBS, M. H. AND J. D. HELM. *Some apparent differences between the erythrocytes of white and negro subjects. *Jour. Cell. Comp. Physiol.*, **22**: 1943.
JACOBS, M. H., DOROTHY R. STEWART AND MARY K. BUTLER. *Some effects of tannic acid on the cell surface. *Amer. Jour. Med. Sci.*, **205**: 1943.
JAEGER, LUCENA. Glycogen utilization by the amphibian gastrula in relation to invagination and induction. *Jour. Cell. Comp. Physiol.*, **25**: 1945.
JANDORF, B. J. AND M. E. KRAHL. Studies on cell metabolism and division. VIII. The diphosphopyridine nucleotide content of eggs of Arbacia punctulata. *Jour. Gen. Physiol.*, **25**: 1942.
JONES, E. R. *The morphology of Enterostomula graffi. *Jour. Morph.*, **68**: 1941.
JONES, E. R. AND W. J. HAYES, JR. *Microdalyellia gilesi, a new Turbellarian worm from Mountain Lake, Va. *Amer. Midland Naturalist*, **26**: 1941.

KALISS, NATHAN. *See* Furth, Boon and Kaliss, 1944.
KAWATA, N. *See* Steinbach, Spiegelman and Kawata, 1944.
KAYLOR, C. T. *Studies on experimental haploidy in salamander larvae. *Biol. Bull.*, **81**: 1941.
KAYLOR, C. T. *Sex differentiation in two androgenetic salamander larvae. *Anat. Rec.*, **87**: 1943.
KELTCH, ANNA K. *See* Krahl, Keltch, Neubeck and Clowes, 1941; Hutchens, Keltch, Krahl and Clowes, 1942.
KIDDER, G. W. *Growth studies on ciliates. VII. Comparative growth characteristics of four species of sterile ciliates. *Biol. Bull.*, **80**: 1941.
KIDDER, G. W. *See* also Claff, Dewey and Kidder, 1941; Burt, Kidder and Claff, 1941.
KNOWLTON, F. P. Observations on the dual contraction of crustacean muscle. *Biol. Bull.*, **82**: 1942.
KNOWLTON, F. P. An investigation of inhibition by direct stimulation of the turtle's heart. *Amer. Jour. Physiol.*, **135**: 1942.
KNOWLTON, F. P. The action of certain drugs on crustacean muscle. *Jour. Exp. Pharmacol. Exp. Therap.*, **75**: 1942.
KNOWLTON, F. P. *Inhibition of the turtle's atria by single induction shocks applied directly. *Amer. Jour. Physiol.*, **140**: 1943.
KOPAC, M. J. Disintegration of the fertilization membrane of Arbacia by the action of an "enzyme." *Jour. Cell. Comp. Physiol.*, **18**: 1941.
KOPAC, M. J. *See* also Hutchens, Kopac and Krahl, 1942.
KRAHL, M. E. *See* also Hutchens, Keltch, Krahl and Clowes, 1942; Jandorf and Krahl, 1942; Hutchens, Kopac and Krahl, 1942.
KRAHL, M. E., A. K. KELTCH, C. E. NEUBECK AND G. H. A. CLOWES. Studies on cell metabolism and cell division. V. Cytochrome oxidase activity in eggs of Arbacia punctulata. *Jour. Gen. Physiol.*, **24**: 1941.
KRAHL, M. E., B. J. JANDORF AND G. H. A. CLOWES. Studies on cell metabolism and cell division. VII. Observations on the amount and possible function of diphosphothiamine in eggs of Arbacia punctulata. *Jour. Gen. Physiol.*, **25**: 1942.
KRASNOW, FRANCES. *The physiological significance of phospholipid in human saliva. *Jour. Dental Res.*, **24**: 1945.
LANCEFIELD, REBECCA C. *Studies on the antigenic composition of Group A hemolytic streptococci. I. Effects of proteolytic enzymes on streptococcal cells. *Jour. Exp. Med.*, **78**: 1943.
LANCEFIELD, REBECCA C. AND W. A. STEWART. *II. The occurrence of strains in a given type containing M but no T antigen. *Jour. Exp. Med.*, **79**: 1944.
LAVIN, G. J. Some observations with a simplified quartz microscope. *Biol. Bull.*, **83**: 1942 (abs.).
LAVIN, G. J. *Simplified ultraviolet microscopy. *Rec. Scientific Instruments*, **14**: 1943.
LAVIN, G. J. *See* also Costello and Lavin, 1943; Harvey and Lavin, 1944; Hibbard and Lavin, 1945.
LAZAROW, ARNOLD. *The chemical organisation of the cytoplasm. *Biol. Bull.*, **87**: 1944.
LEE, R. E. The occurrence of female sword-fish in southern New England waters, with a description of their reproductive condition. *Copeia*, 1942.
LEE, R. E. The hypophysis of the broad-billed sword-fish, Xiphias gladius. *Biol. Bull.*, **82**: 1942.
LEE, R. E. Notes on the color changes of the sea robin, with special reference to the erythrophores. *Jour. Exp. Zool.*, **91**: 1942.
LEE, R. E. Pituitary function in the chromatic physiology of Opsanus tau. *Biol. Bull.*, **83**: 1942 (abs.).
LEE, R. E. *A quantitative survey of the invertebrate bottom fauna in Menemsha Bight. *Biol. Bull.*, **86**: 1944.
LEE, R. E. *See* also Chambers, Zweifach, Lowenstein and Lee, 1944; Zweifach, Lee, Hyman and Chambers, 1944.
LEFEVRE, P. F. Certain chemical factors influencing artificial activation of Nereis eggs. *Biol. Bull.*, **89**: 1945.
LEVY, MILTON AND A. H. PALMER. *Amino peptidase. *Jour. Biol. Chem.*, **150**: 1943.
LEWIS, L. A. *See* Hartman, Lewis, Brownell, Shelden and Walther, 1941; Hartman, Lewis, Brownell, Angerer and Shelden, 1944.

LEWIS, MARGARET R. *The failure of purified penicillin to retard the growth of sarcoma in mice. *Science*, **100**: 1944.
LEWIS, MARGARET R. *A study of inducement and transplantability of sarcoma in rats. *Growth*, **9**: 1945.
LEWIS, W. H. The superficial gel layer and its role in development. *Biol. Bull.*, **87**: 1944.
LIEBMAN, EMIL. *The coelomocytes of Lumbricidae. *Jour. Morph.*, **71**: 1942.
LILLIE, F. R. Further experiments on artificial parthenogenesis in starfish eggs, with a review. *Physiol. Zool.*, **14**: 1941.
LILLIE, F. R. The Woods Hole Marine Biological Laboratory. Univ. Chicago Press, 1944.
LILLIE, R. S. *The problem of synthesis in Biology. *Philosoph. Science*, **9**: 1942.
LILLIE, R. S. *Living systems and non-living systems. *Philosoph. Science*, **9**: 1942.
LILLIE, R. S. *The psychic factor in living organisms. *Philosoph. Science*, **10**: 1943.
LILLIE, R. S. *Vital organization and the psychic factor. *Philosoph. Science*, **11**: 1944.
LILLIE, R. S. *General Biology and Philosophy of the Organism. *Univ. Chicago Press*, 1945.
LITTLE, E. P. *See* Evans, Slaughter, Little and Failla, 1942.
LLOYD, D. P. C. *Activity in neurons of the bulbospinal correlation system. *Jour. Neurophysiol.*, **4**: 1941.
LOEWI, OTTO. *Chemical transmission of nerve impulses. *Science Progress*, **4**: 1945.
LOEWI, OTTO. *Aspects of the transmission of the nervous impulse. *Jour. Mt. Sinai Hosp.*, **12**: 1945.
LUCAS, A. M. AND J. SNEDECOR. Coordination of ciliary movement in the Modiolus gill. *Biol. Bull.*, **81**: 1941 (abs.).
LUCKE, BALDUIN, A. K. PARPART AND R. A. RICCA. Failure of choleic acids in carcinogenic hydrocarbons to alter permeability of marine eggs and of mammalian erythrocytes. *Cancer Research*, **1**: 1941.
LURIA, S. E., M. DELBRUCK AND T. F. ANDERSON. Electron microscope studies of bacterial viruses. *Jour. Bact.*, **46**: 1943.
LYNN, W. G. *The embryology of Eleutherodactylus nubicola, an anuran which has no tadpole stage. *Carnegie Contrib. to Embryol.*, **30**: 1942.
LYNN, W. G. AND J. M. DENT. Notes on Plethodon cinereus and Hemidactylium scutatum on Cape Cod. *Copeia*, 1941.
MACLEAN, BERNICE. *See* Shapiro, 1945.
MARSLAND, D. A. *Protoplasmic streaming. *Chronica Botan.*, **6**: 1941.
MARSLAND, D. A. *Protoplasmic streaming. *Collecting Net*, **16**: 1941.
MARSLAND, D. A. *Protoplasmic streaming in relation to gel structure in the cytoplasm. Chapter in *The Structure of Protoplasm*, Iowa State College Press, 1942.
MARSLAND, D. A. The contractile mechanism in unicellular chromatophores. *Biol. Bull.*, **83**: 1942 (abs.).
MARSLAND, D. A. *Quieting Paramoecium for the elementary student. *Science*, **98**: 1943.
MARSLAND, D. A. Mechanism of pigment displacement in unicellular chromatophores. *Biol. Bull.*, **87**: 1944.
MARSLAND, D. A. *Principles of Modern Biology. Holt and Co., New York, 1945.
MARSLAND, D. A. AND D. E. S. BROWN. The action of pressure on sol-gel equilibria. *Anat. Rec.*, **81**: Suppl., 1941.
MARSLAND, D. A. AND D. E. S. BROWN. The effects of pressure on sol-gel equilibria, with special reference to myosin and other protoplasmic gels. *Jour. Cell. Comp. Physiol.*, **20**: 1942.
MARSLAND, D. A. AND R. RUGH. *Effects of pressure on maturation, cleavage, and early development of the frog's egg. *Anat. Rec.*, **82**: 1942.
MARSLAND, D. A. AND R. RUGH. *The effect of hydrostatic pressure upon the early development of the frog's egg. *Proc. Amer. Philosoph. Soc.*, **86**: 1943.
MARTIN, W. E. Cerama solemyae, probably a blood fluke from the marine pelecypod, Solemya velum. *Jour. Parasitol.*, **30**: 1944.
MARTIN, W. E. Studies on trematodes of Woods Hole. IV. Additional observations upon Cercaria loossi developing in an Annelid. *Trans. Amer. Micro. Soc.*, **63**: 1944.
MARTIN, W. E. Two new species of marine cercariae. *Trans. Amer. Micro. Soc.*, **64**: 1945.
MAST, S. O. *The hydrogen ion concentration of the content of the food vacuoles and the cytoplasm in Amoeba and other phenomena concerning the food vacuoles. *Biol. Bull.*, **83**: 1942.

MAST, S. O. A new peritrich belonging to the genus Ophridium. *Trans. Amer. Mic. Soc.*, **63**: 1944.

MAST, S. O. *See* also Bertholf and Mast, 1944; Grave and Mast, 1944.

MAST, S. O. AND D. L. HOPKINS. *Regulation of the water content of Amoeba mira and adaptation to changes in the osmotic concentration of the surrounding medium. *Jour. Cell. Comp. Physiol.*, **17**: 1941.

MAST, S. O. AND D. M. PACE. *The effect of phosphorus on metabolism in Chilomonas paramoecium. *Jour. Cell. Comp. Physiol.*, **20**: 1942.

MAST, S. O. AND W. G. BOWEN. *The food vacuole in the Peritricha, with special reference to the hydrogen ion concentration of its content and of the cytoplasm. *Biol. Bull.*, **87**: 1944.

MCELROY, W. D. *See* Harvey, Barnes, McElroy, Whitely, Pease and Cooper, 1944.

MELLAND, A. M. *See* Buck and Melland, 1942.

MENKIN, VALY. *Studies on the chemical basis of fever. *Biol. Bull.*, **87**: 1944.

MERWIN, RUTH M. *See* Allee and Merwin, 1941; Allee, Finkel, Garner, Merwin and Evans, 1942; Allee and Merwin, 1943.

METZ, C. B. *The inactivation of fertilizin and its conversion to the "univalent" form by X-rays and ultraviolet light. *Biol. Bull.*, **82**: 1942.

METZ, C. B. *The agglutination of starfish sperm by fertilizin. *Biol. Bull.*, **89**: 1945.

MEYERHOF, BETTINA. *See* Nachmansohn and Meyerhof, 1941.

MEYERHOF, OTTO. *Nature, function, and distribution of the phosphagens in the animal kingdom. *Collecting Net*, **16**: 1941.

MICHAELIS, L. AND SAM GRANICK. *Metachromasy of basic dye stuffs. *Jour. Amer. Chem. Soc.*, **67**: 1945.

MILLER, J. A. Some effects of covering the perisarc upon tubularian regeneration. *Biol. Bull.*, **83**: 1942.

MIRSKY, A. E. *See* Pollister and Mirsky, 1942, 1943.

MOOG, FLORENCE. The influence of temperature on reconstitution in Tubularia. *Biol. Bull.*, **81**: 1941 (abs.).

MOOG, FLORENCE. Some effects of temperature in the regeneration of Tubularia. *Biol. Bull.*, **83**: 1942 (abs.).

MOOG, FLORENCE. *See* also Spiegelman and Moog, 1944.

MOOG, FLORENCE AND S. SPIEGELMAN. Effects of some respiratory inhibitors on respiration and reconstitution in Tubularia. *Proc. Soc. Exp. Biol. Med.*, **49**: 1942.

MORGAN, T. H. *Further experiments in cross- and self-fertilization of Ciona at Woods Hole and Corona del Mar. *Biol. Bull.*, **80**: 1941.

MORGAN, T. H. Cross- and self-fertilization in the Ascidian, Styela. *Biol. Bull.*, **82**: 1942.

MORGAN, T. H. Cross- and self-fertilization in the Ascidian, Molgula manhattensis. *Biol. Bull.*, **82**: 1942.

MUIR, R. M. Effect of radiation from radioactive isotopes on the protoplasm of Spirogyra. *Jour. Cell. Comp. Physiol.*, **19**: 1942.

NACHMANSOHN, DAVID. On the mechanism of transmission of nerve impulses. *Collecting Net*, **17**: 1942.

NACHMANSOHN, DAVID. On the energy source of the nerve action potential. *Biol. Bull.*, **87**: 1944.

NACHMANSOHN, DAVID AND B. MEYERHOF. Relation between electrical changes during nerve activity and concentration of choline esterase. *Jour. Neurophysiol.*, **4**: 1941.

NACHMANSOHN, DAVID AND H. B. STEINBACH. On the localization of enzymes in nerve fibers. *Science*, **95**: 1942.

NACHMANSOHN, DAVID AND H. B. STEINBACH. Localization of enzymes in nerves. 1. Succinic dehydrogenase and vitamin B_1. *Jour. Neurophysiol.*, **5**: 1942.

NAVEZ, A. E., J. D. CRAWFORD, D. BENEDICT AND A. B. DUBOIS. On the metabolism of the heart of Venus mercenaria. *Biol. Bull.*, **81**: 1941.

NETSKY, M. G. AND M. H. JACOBS. Some effects of desoxycorticosterone and related compounds on the mammalian red cell. *Biol. Bull.*, **81**: 1941.

NEUBECK, C. E. *See* Krahl, Keltch, Neubeck and Clowes, 1941.

O'BRIEN, J. P. *Studies on the effects of X-rays on regeneration in the fragmenting oligochaete, Nais paraguayensis. *Growth*, **6**: 1942.

OLSON, MAGNUS. Histology of the radula protractor muscles of Busycon canaliculatum. *Biol. Bull.*, **82**: 1942.

OPPENHEIMER, JANE M. The anatomical relationships of abnormally located Mauther's cells in Fundulus embryos. *Jour. Comp. Neurol.*, **74**: 1941.
ORMSBEE, R. A. *The normal growth of Tetrahymena geleii. *Biol. Bull.*, **82**: 1942.
OSBORN, C. M. Studies on the growth of integumentary pigment in the lower vertebrates. *I. The origin of artificially developed melanophores on the normally unpigmented ventral surface of the summer flounder. *Biol. Bull.*, **81**: 1941.
OSBORN, C. M. II. The role of the hypophysis in melanogenesis in the common catfish. *Biol. Bull.*, **81**: 1941.
OSTERHOUT, W. J. V. Some properties of protoplasmic gels. I. Tension in the chloroplast of Spirogyra. *Jour. Gen. Physiol.*, **29**: 1945.
PACE, D. M. *See* Mast and Pace, 1942.
PACKARD, CHARLES. *Roentgen radiation in biological research. *Radiology*, **45**: 1945.
PACKARD, CHARLES AND F. M. EXNER. *Comparison of physical and biological methods of depth dose measurement. *Radiology*, **44**: 1945.
PARK, THOMAS. The laboratory population as a test of a comprehensive ecological system. *Quart. Rev. Biol.*, **16**: 1941.
PARK, THOMAS, ELLA V. GREGG AND CATHERINE Z. LUTHERMAN. *Studies in population physiology. X. Interspecific competition in populations of granary beetles. *Physiol. Zool.*, **14**: 1941.
PARKER, G. H. Melanophore bands and areas due to nerve cutting, in relation to the protracted activity of nerves. *Jour. Gen. Physiol.*, **24**: 1941.
PARKER, G. H. The methods of excitation of melanophores in the skin of the catfish Ameiurus. *Science*, **93**: 1941.
PARKER, G. H. Limited responses of melanophores as determined by activating agents. *Science*, **93**: 1941.
PARKER, G. H. The responses of catfish melanophores to ergotamine. *Biol. Bull.*, **81**: 1941.
PARKER, G. H. The organization of the melanophore system in bony fishes. *Biol. Bull.*, **81**: 1941.
PARKER, G. H. Hypersensitization of catfish melanophores to adrenalin by denervation. *Biol. Bull.*, **81**: 1941.
PARKER, G. H. The method of activation of melanophores and the limitations of melanophore responses in the catfish Ameiurus. *Proc. Amer. Philosoph. Soc.*, **85**: 1941.
PARKER, G. H. The activity of peripherally stored neurohumors in catfishes. *Jour. Gen. Physiol.*, **25**: 1941.
PARKER, G. H. *Color changes in Mustelus and other elasmobranch fishes. *Jour. Exp. Zool.*, **89**: 1942.
PARKER, G. H. *Sensitization of melanophores by nerve cutting. *Proc. Nat. Acad. Sci.*, **28**: 1942.
PARKER, G. H. Methods of estimating the effects of melanophore changes in animal coloration. *Biol. Bull.*, **84**: 1943.
PARKER, G. H. Color changes in the American eel, Anguilla rostrata. *Anat. Rec.*, **87**: 1943.
PARKER, G. H. *The time factor in chromatophore responses. *Proc. Amer. Philosoph. Soc.*, **87**: 1944.
PARKER, G. H. Melanophore activators in the common American eel Anguilla rostrata. *Jour. Exp. Zool.*, **98**: 1945.
PARPART, A. K. Lipoprotein complexes in the egg of Arbacia. *Biol. Bull.*, **81**: 1941.
PARPART, A. K. The preparation of red cell membranes. *Jour. Cell. Comp. Physiol.*, **19**: 1942.
PARPART, A. K. *See* also Lucke, Parpart and Ricca, 1941; Chase, Lorenz, Parpart and Gregg, 1944.
PARPART, A. K. AND R. BALLENTINE. *Hematocrit determination of red cell volume. *Science*, **98**: 1943.
PEASE, D. C. *See* Harvey, Barnes, McElroy, Whitely, Pease and Cooper, 1944.
PIERCE, MADELENE E. Response of melanophores of the skin to injections of adrenalin, with special reference to body weight of the animal. *Jour. Exp. Zool.*, **86**: 1941.
PLOUGH, H. H. *Spontaneous mutability in Drosophila. *Cold Spring Harbor Symposia*, **9**: 1941.
PLOUGH, H. H. *Temperature and evolution. *Biol. Symposia*, **6**: 1942.
POLLISTER, A. W. *Mitochondrial orientations and molecular patterns. *Physiol. Zool.*, **14**: 1941.

POLLISTER, A. W. AND A. E. MIRSKY. *Nucleoproteins of cell nuclei. *Proc. Nat. Acad. Sci.*, **28**: 1942.

POLLISTER, A. W. AND A. E. MIRSKY. *Studies on the chemistry of chromatin. *Trans. N. Y. Acad. Sci.*, **5**: 1943.

POLLISTER, A. W. AND A. E. MIRSKY. *Fibrous nucleoproteins of chromatin. *Biol. Symposia*, **10**: 1943.

POLLISTER, A. W. AND P. F. POLLISTER. *Relation between centriole and centromere in a typical spermatogenesis of viviparid snails. *Ann. N. Y. Acad. Sci.*, **45**: 1943.

PRICE, DOROTHY. *A comparison of the reactions of male and female rat prostate transplants. *Anat. Rec.*, **82**: 1942.

PROSSER, C. L. An analysis of the action of acetylcholine on hearts, particularly in Arthopods. *Biol. Bull.*, **83**: 1942.

PROSSER, C. L. Single unit analysis of the heart ganglion discharge in Limulus polyphemus. *Jour. Cell. Comp. Physiol.*, **21**: 1943.

PROSSER, C. L. AND G. L. ZIMMERMAN. Comparative pharmacology of myogenic and neurogenic hearts. *Biol. Bull.*, **81**: 1941 (abs.).

QUINN, GERTRUDE P. *See* Hiatt and Quinn, 1945.

RECKNAGEL, RICHARD. *See* Wilbur and Recknagel, 1943.

REID, W. M. *The relationship between glycogen depletion in the nematode Ascaridia galli and the elimination of the parasite by the host. *Amer. Jour. Hyg.*, **41**: 1945.

REID, W. M. **In vivo* and *in vitro* glycogen utilization in the fowl nematode Ascaridia galli. *Biol. Bull.*, **89**: 1945 (abs.).

REINHARD, E. G. A hermit crab as intermediate host of Polymorphus. *Jour. Parasitol.*, **30**: 1944.

REINHARD, E. G. Paguritherium alatum, an entoniscian parasite of Pagurus longicarpus. *Jour. Parasitol.*, **31**: 1945.

RICCA, R. A. *See* Lucke, Parpart and Ricca, 1941.

RICHARDS, A. G. The interfibrillar material in the central nervous system of mosquito larvae. *Biol. Bull.*, **83**: 1942 (abs.).

RICHARDS, A. G. *Lipid nerve sheaths in insects and their probable relation to insecticide action. *Jour. N. Y. Entomol. Soc.*, **51**: 1943.

RICHARDS, A. G. *The structure of living insect nerves and nerve sheaths as deduced from the optical properties. *Jour. N. Y. Entomol. Soc.*, **52**: 1944.

RICHARDS, A. G. AND JANE L. WEYGANT. *The selective penetration of fat solvents into the nervous system of mosquito larvae. *Jour. N. Y. Entomol. Soc.*, **53**: 1945.

RICHARDS, A. G., H. B. STEINBACH AND T. F. ANDERSON. Electron microscope studies of squid giant nerve axoplasm. *Jour. Cell. Comp. Physiol.*, **21**: 1943.

RIS, HANS. *A cytological and experimental analysis of the meiotic behavior of the univalent X-chromosome in the bearberry aphid Tamalia. *Jour. Exp. Zool.*, **90**: 1942.

RIS, HANS. *A quantitative study of anaphase movement in the aphid Tamalia. *Biol. Bull.*, **85**: 1943.

RIS, HANS AND HELEN CROUSE. *Structure of the salivary gland chromosomes of Diptera. *Proc. Nat. Acad. Sci.*, **31**: 1945.

ROBBIE, W. A. Balanced centerwell solutions for manometric experimentation. *Biol. Bull.*, **89**: 1945 (abs.).

ROGICK, MARY D. Resistance of fresh water Bryozoa to dessication. *Biodynamica*, **3**: 1941.

ROGICK, MARY D. Supplementary note on the effect of the 1938 hurricane. *Ohio J. Sci.*, **41**: 1941.

ROGICK, MARY D. *Studies on fresh-water Bryozoa XV. Hyalinella punctata growth data. *Ohio Jour. Sci.*, **45**: 1945.

ROGICK, MARY D. Field trips with a long-range purpose. *Amer. Biol. Teacher*, **7**: 1945.

ROGICK, MARY D. Studies on marine Bryozoa. I. Aeverrillia setigera. *Biol. Bull.*, **89**: 1945.

ROGICK, MARY D. *Studies on fresh-water Bryozoa. XVI. Fredericella australiensis. *Biol. Bull.*, **89**: 1945.

ROGICK, MARY D. "Calcining" specimens. *Amer. Biol. Teacher*, **8**: 1945.

ROOT, R. W. AND LAURENCE IRVING. The equilibrium between hemoglobin and oxygen in whole and hemolyzed blood of the tautog, with a theory of the Haldane effect. *Biol. Bull.*, **81**: 1941.

ROSE, S. M. *A method for inducing limb regeneration in adult Anura. *Proc. Soc. Exp. Biol. Med.*, **49**: 1942.
ROSE, S. M. *Causes for loss of regenerative power in adult Anura. *Anat. Rec.*, **89**: 1944.
ROSE, S. M. *Methods for initiating limb regeneration in adult Anura. *Jour. Exp. Zool.*, **95**: 1944.
ROSE, S. M. *The effect of NaCl in simulating regeneration of limbs of frogs. *Jour. Morph.*, **77**: 1945.
ROSE, S. M. AND FLORENCE C. ROSE. The role of a cut surface in Tubularia regeneration. *Physiol. Zool.*, **14**: 1941.
ROSE, S. M. *See* also Gidge and Rose, 1944.
RUGH, ROBERT. *See* Marsland and Rugh, 1942.
RUNYON, E. H. Aggregation of separate cells of Dictyostelium to form a multicellular body. *Biol. Bull.*, **83**: 1943 (abs.).
SANDOW, ALEXANDER. Studies of the muscle twitch recorded by electronic methods. *Biol. Bull.*, **89**: 1945 (abs.).
SAYLES, L. P. Regeneration in the polychaete, Clymenella torquata. *Biol. Rev. of the City College, N. Y.*, **3**: 1941.
SAYLES, L. P. Buds induced in Clymenella torquata by implants of nerve cord and neighboring tissues derived from the mid-body region of worms of the same species. *Biol. Bull.*, **82**: 1942.
SAYLES, L. P. Implants consisting of young buds, formed in anterior regeneration in Clymenella, plus the nerve cord of the adjacent old part. *Jour. Exp. Zool.*, **94**: 1943.
SCHAEFFER, MORRIS. *Preparation of influenza virus. *Proc. Soc. Exp. Biol. Med.*, **51**: 1942.
SCHALLEK, WILLIAM. The reaction of certain Crustacea to direct and to diffuse light. *Biol. Bull.*, **84**: 1943.
SCHALLEK, WILLIAM. Action of potassium on bound acetylcholine in lobster nerve cord. *Jour. Cell Comp. Physiol.*, **26**: 1945.
SCHARRER, BERTA. *Neurosecretion. II. Neurosecretory cells in the central nervous system of cockroaches. *Jour. Comp. Neurol.*, **74**: 1941.
SCHARRER, BERTA. III. The cerebral organ of the nemerteans. *Jour. Comp. Neurol.*, **74**: 1941.
SCHARRER, BERTA. IV. Localization of neurosecretory cells in the central nervous system of Limulus. *Biol. Bull.*, **81**: 1941.
SCHARRER, BERTA. *Endocrines in Invertebrates. *Physiol. Rev.*, **21**: 1941.
SCHARRER, BERTA. *Experimental tumors after nerve section in an insect. *Proc. Soc. Biol. Med.*, **60**: 1945.
SCHARRER, BERTA. *See* also Scharrer and Scharrer, 1945.
SCHARRER, BERTA AND E. SCHARRER. Neurosecretion VI. A comparison between the intercerebralis-cardiacumallatum system of the insects and the hypothalamo-hypophyseal system of the vertebrates. *Biol. Bull.*, **87**: 1944.
SCHARRER, ERNST. Neurosecretion I. The nucleus preopticus of Fundulus. *Jour. Comp. Neurol.*, **74**: 1941.
SCHARRER, ERNST. The capillary bed of the central nervous system of certain invertebrates. *Biol. Bull.*, **87**: 1944.
SCHARRER, ERNST. *The blood vessels of the nervous tissue. *Quart. Rev. Biol.*, **19**: 1944.
SCHARRER, ERNST. Capillaries and mitochrondria in neurophil. *Jour. Comp. Neurol.*, 1945.
SCHARRER, ERNST. *See* also Scharrer and Scharrer, 1944.
SCHARRER, ERNST, S. L. PALAY AND R. G. NILGES. Neurosecretion VIII. The Nissl substance in secreting nerve cells. *Anat. Rec.*, **92**: 1945.
SCHARRER, ERNST AND BERTA SCHARRER. Neurosecretion. *Physiol. Rev.*, **25**: 1945.
SCHECHTER, VICTOR. Experimental studies upon the egg cells of the clam, Mactra solidissima, with special reference to longevity. *Jour. Exp. Zool.*, **86**: 1941.
SCHECHTER, VICTOR. *Oxygen as a factor in the polarity of Corymorpha palma. *Physiol. Zool.*, **14**: 1941.
SCHECHTER, VICTOR. *Tolerance of the snail, Thais floridana to waters of low salinity and the effect of size. *Ecology*, **24**: 1943.
SCHECHTER, VICTOR. *Two flatworms from the oyster-drilling snail, Thais floridana. *Jour. Parasitol.*, **29**: 1943.
SCHMITT, F. O. *Structural proteins of cells and tissues. In *Advances in Protein Chemistry*, **1**: 1945.

SCOTT, ALLAN. Reversal of sex production in Micromalthus. *Biol. Bull.*, **83**: 1942 (abs.).
SCOTT, SISTER FLORENCE MARIE. The early embryonic development of Amaroecium constellatum. *Biol. Bull.*, **83**: 1942 (abs.).
SCOTT, SISTER FLORENCE MARIE. The developmental history of Amaroecium constellatum. 1. Early embryonic development. *Biol. Bull.*, **88**: 1945.
SEVAG, M. G. **Immuno-catalysis.* C. C. Thomas, Springfield, Ill., 1945.
SHAEFFER, A. A. A fourteen day rhythm in the left-right spiralling ratio of Flabellula citata. *Biol. Bull.*, **83**: 1942 (abs.).
SHANES, A. M. Current, voltage, and resistance characteristics of injured nerves. *Biol. Bull.*, **87**: 1944 (abs.).
SHANES, A. M. Frog nerve as a generator of current and voltage. *Jour. Cell. Comp. Physiol.*, **24**: 1944.
SHANES, A. M. Evidence of a metabolic effect by potassium in lowering the injury potential of invertebrate nerve. *Biol. Bull.*, **89**: 1945 (abs.).
SHAPIRO, H. H. AND BERNICE L. MACLEAN. *Transplantation of developing tooth germs in the mandible of the cat. *Jour. Dental Res.*, **24**: 1945.
SHAPIRO, HERBERT. Oxygen utilization by starfish eggs. *Amer. Jour. Physiol.*, **133**: 1941.
SHAPIRO, HERBERT. Metabolism and fertilization in the starfish egg. *Collecting Net*, **16**: 1941.
SHAPIRO, HERBERT. Centrifugal elongation of cells, and some conditions governing the return to sphericity, and cleavage time. *Jour. Cell. Comp. Physiol.*, **18**: 1941
SHAPIRO, HERBERT. Water permeability of the Chaetopterus egg before and after fertilization. *Jour. Cell. Comp. Physiol.*, **18**: 1941.
SHAPIRO, HERBERT AND HUGH DAVSON. Permeability of the Arbacia egg to potassium. *Biol. Bull.*, **81**: 1941.
SHAPIRO, HERBERT. Metabolism and fertilization in the starfish egg. *Biol. Bull.*, **81**: 1941.
SHAPIRO, HERBERT. The speed of membrane formation. *Anat. Rec.*, **81**: 1941.
SHAPIRO, HERBERT. *See* also Harvey and Shapiro, 1941.
SHAW, MYRTLE. *See* Sickles and Shaw, 1941.
SHELDEN, F. F. *See* Hartman, Lewis, Brownell and Shelden, 1941; Hartman, Shelden and Green, 1943; Hartman, Lewis, Brownell, Angerer, and Shelden, 1944.
SICHEL, F. J. M. *The relative elasticity of the sarcolemma and of the entire skeletal muscle fiber. *Amer. Jour. Physiol.*, **133**: 1941.
SICHEL, F. J. M. *See* also Harvey and Sichel, 1942, 1945.
SICKLES, GRACE M. AND MYRTLE SHAW. The production of specific antisera for enzymes that decompose pneumococcus carbohydrates types 3 and 8. *Jour. Bacteriol.*, **42**: 1941.
SLAUGHTER, J. C. *See* Evans, Slaughter, Little, and Failla, 1942.
SLIFER, ELEANOR H. *A mutant stock of Drosophila with extra sex-combs. *Jour. Exp. Zool.* **90**: 1942.
SLIFER, ELEANOR H. *The internal genitalia of some previously unstudied species of female Acrididae. *Jour. Morph.* **72**: 1943.
SLIFER, ELEANOR H. *The internal genitalia of female Tetrigidae, Eumastacidae, and Proscopiidae. *Jour. Morph.*, **73**: 1943.
SMELSER, G. K. The oxygen consumption of eye muscles of thyroid-ectomized and thyroxin injected guinea pigs. *Amer. Jour. Physiol.*, **142**: 1944.
SMITH, M. E. *See* Evans, Beams, and Smith, 1941.
SOSA, J. M. *Woods Hole, Acropolis de los biologos. *El. Dia.*, 1943.
SOSA, J. M. *Quince meses en los Estados Unidos de Norte America. *Anales Facultad de Med. Montevideo*, **30**: 1945.
SPIEGELMAN, S. Mass and time relationships in the regeneration of Tubularia. *Biol. Bull.*, **83**: 1942 (abs.).
SPIEGELMAN, S. *See* also Moog and Spiegelman, 1942; Steinbach and Spiegelman, 1943, 1944.
SPIEGELMAN, S. AND A. GOLDIN. A comparison of regeneration and respiration rates of Tubularia. *Proc. Soc. Exp. Biol. Med.* **55**: 1944.
STEINBACH, H. B. Chloride in the giant axons of the squid. *Jour. Cell. Comp. Physiol.*, **17**: 1941.
STEINBACH, H. B. *See* also Nachmansohn and Steinbach, 1942; Richards, Steinbach and Anderson, 1943.

STEINBACH, H. B. AND S. SPIEGELMAN. The sodium and potassium balance in squid nerve axoplasm. *Jour. Cell. Comp. Physiol.*, **22**: 1943.

STEINBACH, H. B. AND N. KAWATA. The recovery of the cut surface of the scallop muscle. *Fed. Proc.*, **3**: 1944.

STEINBACH, H. B., S. SPIEGELMAN AND N. KAWATA. Rectification and injury potential in squid axons. *Fed. Proc.*, **3**: 1944.

STEINBACH, H. B., S. SPIEGELMAN AND N. KAWATA. The effects of potassium and calcium on the electrical properties of squid axons. *Jour. Cell. Comp. Physiol.* **24**: 1944.

STERN, K. G. *Oxidases, Peroxidases, and Catalase. *Symposium on respiratory enzymes.* Madison, Wis., 1942.

STERN, K. G. Physical-chemical studies on chromosomal nucleoproteins. *Biol. Bull.*, **89**: 1945 (abs.).

STERN, K. G. AND S. F. VELICK. The effect of centrifugation upon the oxygen consumption of Arbacia eggs. *Biol. Bull.*, **81**: 1941.

STEWART, DOROTHY R. *See* Jacobs and Stewart, 1941, 1942, 1945; Jacobs, Stewart and Butler, 1943.

STEWART, DOROTHY R. AND M. H. JACOBS. The role of carbonic anhydrase in the catalysis of ionic exchanges by bicarbonates. *Biol. Bull.*, **81**: 1941 (abs.).

STEWART, W. A. *See* Lancefield and Stewart, 1944.

STILES, K. A. **Handbook of microscopic characteristics of tissues and organs.* Blakiston, 1943.

STILES, K. A. **Laboratory explorations in general zoology.* Macmillan, 1943.

STOKEY, ALMA G. *Gametophytes of Marattia sambucina and Macroglossum Smithii. *Bot. Gaz.*, **103**: 1942.

STOKEY, ALMA G. *The gametophyte of Dipteria conjugata. *Bot. Gaz.*, **106**: 1945.

STUNKARD, H. W. Specificity and host-relations in the trematode genus Zoogonus. *Biol. Bull.*, **81**: 1941.

STUNKARD, H. W. Pathology and immunity to infection with heterophyid trematodes. *Biol. Bull.*, **81**: 1941.

STUNKARD, H. W. Studies on pathology and resistance in terms and dogs infected with the heterophyid trematode, Cryptocotyle lingua. *Trans. Amer. Microscop. Soc.*, **61**: 1942.

STUNKARD, H. W. The morphology and life history of the digenetic trematode, Zoogonoides laevis. *Biol. Bull.*, **85**: 1943.

TAFT, C. H. The effects of a mixture of high molecular alkyl-dimethyl-benzyl-ammonium chlorides on the isolated heart of Limulus polyphemus. *Proc. and Trans. Texas Acad. Sci.*, **28**: 1945.

TAFT, C. H. The action of amino acids on color changes in Fundulus. *Science*, **101**: 1945.

TAFT, C. H. *Action of quitenine on the living Tautog and Toadfish. *Biol. Bull.*, **89**: 1945 (abs.).

TAFT, C. H. AND J. A. PLACE. *The comparative effects of the subcutaneous injection of quitenine on the kidneys of glomerular and aglomerular fish. *Texas Rep. on Biol. Med.* **2**: 1944.

TAYLOR, W. R. Reappearance of rare New England marine algae. *Rhodora*, **43**: 1941.

TAYLOR, W. R. *Notes on the marine algae of Texas. *Mich. Acad. Sci. Artes. and Letter*, **26**: 1941.

TAYLOR, W. R. *Tropical marine algae of the Arthur Schott Herbarium. *Field Mus. Nat. Hist. Bot.*, **230**: 1942.

TAYLOR, W. R. *Marine algae of the Allan Hancock Expedition to the Caribbean, 1937. *Allan Hancock Atlantic Exped.* **2**: 1942.

TAYLOR, W. R. *Marine algae from Haiti. *Mich. Acad.*, **28**: 1943.

TAYLOR, W. R. **The collecting of seaweeds and fresh water algae. *Instructions to naturalists in the armed forces for botanical work.* 1944 2nd ed. 1945.

TAYLOR, W. R. *William Gilson Farlow, promotor of phycological research in America. *Farlowia*, **2**: 1945.

TAYLOR, W. R. *Pacific marine algae of the Allan Hancock Expeditions to the Galapagos Islands. *Allan Hancock Pacific Exp.* **12**: 1945.

TEWINKEL, LOIS E. Structures concerned with yolk absorption in Squalus acanthias. *Biol. Bull.*, **81**: 1941 (abs.).

TeWinkel, Lois E. Observations on later phases of embryonic nutrition in Squalus acanthias. *Jour. Morph.*, **73**: 1943.

TeWinkel, Lois E. Embryonic nourishment in the spiny dogfish. *Wards Nat. Hist. Bull.*, **19**: 1945.

Thivy, Francesa. A new species of Ectochaete from Woods Hole. *Biol. Bull.*, **83**: 1942.

Thivy, Francesa. New records of some marine Chaetophoraceae and Chaetosphaeridiaceae for North America. *Biol. Bull.*, **85**: 1943.

Trager, William. *The nutrition of invertebrates. *Physiol. Rev.*, **21**: 1941.

Trager, William. *Studies on conditions affecting the survival *in vitro* of a malarial parasite. *Biol. Bull.*, **81**: 1941 (abs.).

Trinkhaus, J. P. *See* Goodrich, Josephson, Trinkhaus and Slate, 1944.

Trombetta, Vivian (Mrs. Roland Walker). The cytonuclear ratio. *Bot. Rev.*, **8**: 1942.

von Dach, Herman. Respiration of a colorless flagellate, Astasia klebsii. *Biol. Bull.*, **82**: 1942.

von Sallman, L. J. K. *Hydrogen ion concentration of the vitreous in the living eye. *Arch. Ophthalmol.*, **33**: 1945.

Walker, Roland and G. C. Bennet. *Size relations in the optic system of telescope-eyed goldfish. *Trans. Connecticut Acad. Art and Sci.*, **36**: 1945.

Walker, Roland. *See* also Freedman and Walker, 1942.

Warren, C. O. *The role of bicarbonate in the action of serum in supporting tissue respiration. *Jour. Biol. Chem.*, **156**: 1944.

Warren, C. O. *The effect of thiouracil on the respiration of bone marrow and leucocytes *in vitro*. *Amer. Jour. Physiol.*, **71**: 1944.

Waterman, A. J. The action of drugs on the compound ascidian, Perophora viridis, as indicated by the activity of the intact heart. *Physiol. Zool.*, **15**: 1942.

Waterman, A. J. Further study of the action of drugs on the heart of the compound ascidian. *Physiol. Zool.*, **16**: 1943.

Watterson, R. L. *Some aspects of pigment deposition in feather germs of chick embryos. *Biol. Bull.*, **81**: 1941 (abs.).

Watterson, R. L. Asexual reproduction in the colonial tunicate Botryllus schlosseri, with special reference to the developmental history of intersiphonal band of pigment cells. *Biol. Bull.* **88**: 1945.

Weidenreich, Franz. *The brachycephalization of recent mankind. Southwestern. *Jour. Anthropol.*, **1**: 1945.

Wenrich, D. H. *The morphology of some protozoan parasites in relation to microtechnique. *Jour. Parasitol.*, **27**: 1941.

Wenrich, D. H. *Observations on the food habits of Entamoeba muris and Entamoeba ranarum. *Biol. Bull.*, **81**: 1941.

Wenrich, D. H. Morphology of the intestinal trichomonad flagellates in man and of similar forms in monkeys, cats, dogs, and rats. *Jour. Morph.*, **74**: 1944.

Wenrich, D. H. Comparative morphology of the trichomonad flagellates of man. *Amer. Jour. Trop. Med.*, **24**: 1944.

Wenrich, D. H. Nuclear structure and nuclear division in Dientamoeba fragilis. *Jour. Morph.*, **74**: 1944.

Wenrich, D. H. Studies on Dientamoeba fragilis. IV. Further observations with an outline of present day knowledge of this species. *Jour. Parasitol.*, **30**: 1944.

Whaley, W. G. and C. Y. Whaley. A developmental analysis of inherited leaf patterns in Tropaeolum. *Amer. Jour. Botany*, **29**: 1942.

Whiting, Anna R. *X-ray sensitivity of first meiotic prophase and metaphase in Habrobracon eggs. *Genetics*, **27**: 1942.

Whiting, Anna R. *Effects of X-rays on hatchability and on chromosomes of Habrobracon eggs treated in first meiotic prophase and metaphase. *Amer. Nat.*, **79**: 1945.

Whiting, P. W. *The cytogenetics of sex determination. *Proc. 7th Internat. Genetical Cong.*, 1941.

Whiting, P. W. *Sex determination in Habrobracon. *Proc. 7th Internat. Genetical Cong.*, 1941.

Whiting, P. W. *Multiple alleles in complementary sex determination of Habrobracon. *Genetics*, **28**: 1943.

WHITING, P. W. *Intersexual females and intersexuality in Habrobracon. *Biol. Bull.*, **85**: 1943.
WHITING, P. W. *Androgenesis in the parasitic wasp Habrobracon. *Jour. Hered.*, **34**: 1944.
WHITING, P. W. *The problem of reversal of male haploidy by selection. *Biol. Bull.*, **89**: 1945 (abs.).
WHITING, P. W. *The evolution of male haploidy. *Quart. Rev. Biol.*, **20**: 1945.
WICHTERMAN, RALPH. *Pure line mass cultures for demonstrating the mating reaction and conjugation in Paramoecium. *Turtox News*, **22**: 1944.
WICHTERMAN, RALPH. *Recent discoveries of nuclear processes and sexual phenomena in Paramoecium. *Turtox News*, **22**: 1944.
WICHTERMAN, RALPH. A modified petri dish for continuous temperature observation. *Science*, **101**: 1945.
WIERCINSKI, F. J. An experimental study of intracellular pH in the Arbacia egg. *Biol. Bull.*, **81**: 1941.
WIERCINSKI, F. J. An experimental study of protoplasmic pH determination. I. Amoebae and Arbacia punctulata. *Biol. Bull.*, **86**: 1944.
WILBUR, K. M. The stimulating action of citrates and oxalates on the Nereis egg. *Physiol. Zool.*, **14**: 1941.
WILBUR, K. M. *See* also Angerer and Wilbur, 1943.
WILBUR, K. M. AND R. O. RECKNAGEL. The radiosensitivity of eggs of Arbacia punctulata in various salt solutions. *Biol. Bull.*, **85**: 1943.
WILHELMI, R. W. *The application of the precipitin technique to theories concerning the origin of vertebrates. *Biol. Bull.*, **82**: 1942.
WILLIAMSON, R. R. *See* Buchsbaum and Williamson, 1943.
WILLIER, B. H. *Melanophore control of the sexual dimorphism of feather pigmentation in the Barred Plymouth Rock. *Biol. Bull.*, **87**: 1944.
WILLIER, B. H. AND MARY E. RAWLES. *Genotypic control of feather color pattern as demonstrated by the effects of a sex-linked gene upon the melanophores. *Genetics*, **29**: 1944.
WILLIER, B. H. AND MARY E. RAWLES. Melanophore control of the sexual dimorphism of feather pigmentation pattern in the Barred Plymouth Rock fowl. *Yale Jour. Biol. Med.*, **17**: 1944.
WITKUS, ELEANOR R. *Some hints on smear technique. *Turtox News*, **23**: 1945.
WITKUS, ELEANOR R. *Endomitotic tapetal cell divisions in Spinacia. *Amer. Jour. Botany*, **32**: 1945.
WITKUS, ELEANOR R. *Endomitosis in plants. *Biol. Bull.*, **89**: 1945 (abs.).
WITKUS, ELEANOR R. *See* also Berger and Witkus, 1943; Berger, Sullivan and Witkus, 1944.
WOODRUFF, L. L. *See* Boell and Woodruff, 1941.
WOODWARD, ALVALYN E. AND J. M. CONDRIN. *Physiological studies on hibernation in the chipmunk. *Physiol. Zool.*, **18**: 1945.
WRINCH, DOROTHY. *The native protein theory of the structure of protoplasm. *Cold Spring Harbor Symposia*, **9**: 1941.
WRINCH, DOROTHY. Proteins in action. *Collecting Net*, **16**: 1941.
WRINCH, DOROTHY. Further implication of flexible protein frameworks. *Collecting Net*, **16**: 1941.
WRINCH, DOROTHY. The structure of biologically active membranes. *Biol. Bull.*, **83**: 1942 (abs.).
WRINCH, DOROTHY. *Native proteins, flexible frameworks and cytoplasmic organization. *Nature*, **150**: 1942.
WRINCH, DOROTHY. *Growth and form. *Isis*, **34**: 1943.
WRINCH, DOROTHY. Native protein crystallography and diffraction patterns. *Biol. Bull.*, **87**: 1944.
WRINCH, DOROTHY. Fourier transforms and structure factors. *Phys. Rev.*, **67**: 1945.
WRINCH, DOROTHY. A tetrahedral framework for native proteins? *Biol. Bull.*, **89**: 1945.
WULFF, V. J. *See* Brown and Wulff, 1941.
YNTEMA, C. L. *An experimental study on the origin of the sensory neurones and sheath cells of the IXth and Xth cranial nerves in Amblystoma punctatum. *Jour. Exp. Zool.*, **92**: 1943.
YNTEMA, C. L. *Experiments on the origin of the sensory ganglia of the facial nerve in the chick. *Jour. Comp. Neur.*, **81**: 1944.

YNTEMA, C. L. AND W. S. HAMMOND. *Depletions and abnormalities in the cervical sympathetic system of the chick following extirpation of neural crest. *Jour. Exp. Zool.*, **100**: 1945.

ZINN, D. J. AND R. W. PERNAK. Mystacocarida, a new order of Crustacea from intertidal beaches in Massachusetts and Connecticut. *Smithsonian Miscellaneous Collections*, **103**: 1943.

ZWEIFACH, B. J., R. E. LEE, C. HYMAN AND R. CHAMBERS. *Omental circulation in morphinized dogs subjected to graded hemorrhage. *Annals Surg.*, **120**: 1944.

ZWEIFACH, B. J. *See* also Chambers and Zweifach, 1944.

ZWEIFACH, B. J., R. G. ABELL, R. CHAMBERS AND G. H. A. CLOWES. Role of the decompensatory reactions of peripheral blood vessels in tourniquet shock. *Surg. Gyn. Obstet.*, **80**: 1945.

2. THE STAFF, 1945

CHARLES PACKARD, Director, Marine Biological Laboratory, Woods Hole, Massachusetts.

SENIOR STAFF OF INVESTIGATION

E. G. CONKLIN, Professor of Zoology, Emeritus, Princeton University.
FRANK R. LILLIE, Professor of Embryology, Emeritus, The University of Chicago.
RALPH S. LILLIE, Professor of General Physiology, Emeritus, The University of Chicago.
C. E. MCCLUNG, Professor of Zoology, Emeritus, University of Pennsylvania.
S. O. MAST, Professor of Zoology, Emeritus, Johns Hopkins University.
A. P. MATHEWS, Professor of Biochemistry, Emeritus, University of Cincinnati.
T. H. MORGAN, Director of the Biological Laboratory, California Institute of Technology.
G. H. PARKER, Professor of Zoology, Emeritus, Harvard University.

ZOOLOGY

I. CONSULTANTS

T. H. BISSONNETTE, Professor of Biology, Trinity College.
L. L. WOODRUFF, Professor of Protozoology, Yale University.

II. INSTRUCTORS

F. A. BROWN, Associate Professor of Zoology, Northwestern University, in charge of course.
T. H. BULLOCK, Assistant Professor of Neurology University of Missouri Medical School.
W. D. BURBANCK, Associate Professor of Biology, Drury College.
C. G. GOODCHILD, Associate Professor of Biology, Southwest Missouri State Teachers College.
JOHN H. LOCHHEAD, Instructor in Zoology, University of Vermont.
MADELENE E. PIERCE, Assistant Professor of Zoology, Vassar College.
W. M. REID, Assistant Professor of Biology, Monmouth College.
MARY D. ROGICK, Professor of Biology, College of New Rochelle.

III. LABORATORY ASSISTANT

ANTOIN BACA, Duke University Medical School.

EMBRYOLOGY

I. CONSULTANTS

H. B. GOODRICH, Professor of Biology, Wesleyan University.

II. Instructors

W. W. Ballard, Professor of Zoology, Dartmouth College.
Donald P. Costello, Professor of Zoology, University of North Carolina.
Viktor Hamburger, Professor of Zoology, Washington University, in charge of course.
Jane M. Oppenheimer, Assistant Professor in Biology, Bryn Mawr College.

III. Research Assistant

Marjorie Hopkins, University of California.

IV. Laboratory Assistants

Catherine Henley, The Johns Hopkins University.
Eleanor Lerner, Washington University.

PHYSIOLOGY

I. Consultants

William R. Amberson, Professor of Physiology, University of Maryland, School of Medicine.
Harold C. Bradley, Professor of Physiological Chemistry, University of Wisconsin.
Walter E. Garrey, Professor of Physiology, Vanderbilt University Medical School.
Merkel H. Jacobs, Professor of Physiology, University of Pennsylvania.

II. Instructors

Robert Ballentine, Lecturer in Zoology, Columbia University (absent in 1945).
Aurin Chase, Assistant Professor of Biology, Princeton University.
Arthur C. Giese, Associate Professor of Biology, Stanford University (absent in 1945).
E. S. Guzman Barron, Associate Professor of Biochemistry, The University of Chicago.
Rudolf T. Kempton, Professor of Zoology, Vassar College (absent in 1945).
Arthur K. Parpart, Associate Professor of Biology, Princeton University, in charge of course.
Robert Ramsey, Associate Professor of Physiology, Medical College of Virginia.

BOTANY

I. Consultants

S. C. Brooks, Professor of Zoology, University of California.
B. M. Duggar, Professor of Plant Physiology, University of Wisconsin.

II. Instructors

Wm. Randolph Taylor, Professor of Botany, University of Michigan, in charge of course.
Hannah Croasdale, Technical Assistant, Dartmouth College.

EXPERIMENTAL RADIOLOGY

G. Failla, Memorial Hospital, New York City.
L. Robinson Hyde, Phillips Exeter Academy, Exeter, N. H.

LIBRARY

Priscilla B. Montgomery (Mrs. Thomas H. Montgomery, Jr.), Librarian
Deborah Lawrence Mrs. Elon H. Jessup Mary A. Rohan

APPARATUS DEPARTMENT

E. P. Little, Phillips Exeter Academy, Exeter, N. H., Manager
J. D. Graham Dorothy LeFevre

CHEMICAL DEPARTMENT

E. P. Little, Phillips Exeter Academy, Exeter, N. H., Manager

SUPPLY DEPARTMENT

James McInnis, Manager
D. J. Zinn, Naturalist

Ruth Crowell Grace M. Kennerson
M. B. Gray W. E. Kahler F. N. Whitman
A. M. Hilton G. Lehy

GENERAL OFFICE

F. M. MacNaught, Business Manager
Polly L. Crowell Mrs. Lila S. Myers

GENERAL MAINTENANCE

T. E. Larkin, Superintendent
W. C. Hemenway G. T. Nickelson, Jr.
R. W. Kahler T. E. Tawell
A. J. Pierce

THE GEORGE M. GRAY MUSEUM

George M. Gray, Curator Emeritus

---

3. Investigators and Students

Independent Investigators, 1945

Abell, Richard G., Assistant Professor of Anatomy, University of Pennsylvania.
Addison, William H. F., Professor of Normal Histology and Embryology, University of Pennsylvania.
Anderson, Rubert S., Assistant Professor of Physiology, University of Maryland.
Anfinson, Christian B., Jr., Instructor in Biological Chemistry, Harvard Medical School.
Armstrong, Philip B., Professor of Anatomy, Syracuse University.
Aronoff, Samuel, Instructor, University of Chicago.
Axelrad, Arthur A., Investigator, McGill University.
Ball, Eric G., Associate Professor of Biological Chemistry, Harvard Medical School.
Ballard, W. W., Professor of Zoology, Dartmouth College.
Ballentine, Robert, Instructor, Columbia University.
Barron, E. S. Guzman, Associate Professor of Biochemistry, The University of Chicago.
Barth, L. G., Associate Professor of Zoology, Columbia University.
Beers, Charles Dale, Professor of Zoology, University of North Carolina.
Berger, Charles A., Professor of Cytology, Fordham University.
Berthold, Lloyd M., Professor of Biology, Western Maryland College.
Bevelander, Gerrit, Associate Professor of Anatomy, New York University.
Bliss, Alfred F., Instructor in Physiology and Pharmacology, Union University.
Bodian, David, Associate in Epidemiology, Johns Hopkins University.

Bronk, Detlev W., Professor of Biophysics, Johnson Foundation.
Brooks, Matilda M., Research Associate in Biology, University of California.
Brooks, Sumner C., Professor of Zoology, University of California.
Brown, Dugald E. S., Professor of Physiology, New York University.
Brown, Frank A., Jr., Associate Professor of Zoology, Northwestern University.
Brownell, Katharine A., Research Associate, Ohio State University.
Budington, Robert A., Professor of Zoology, Emeritus, Oberlin College.
Bullock, Theodore H., Assistant Professor of Anatomy, University of Missouri.
Burbanck, William D., Associate Professor of Biology, Drury College.
Burkholder, Paul R., Professor of Botany, Yale University.
Chambers, Robert, Research Professor of Biology, New York University.
Chase, Aurin M., Assistant Professor of Biology, Princeton University.
Cheney, Ralph H., Chairman Biology Department, Long Island University.
Chidester, F. E., Research Worker, Lee Foundation.
Claff, C. Lloyd, Research Fellow in Surgery, Harvard Medical School.
Clark, Eleanor L., Voluntary Research Worker, University of Pennsylvania.
Clark, Eliot R., Professor of Anatomy, University of Pennsylvania.
Claude, Albert, The Rockefeller Institute for Medical Research.
Clement, A. C., Associate Professor in Biology, College of Charleston.
Clowes, G. H. A., Director of Research, Lilly Research Laboratories.
Conklin, Edwin G., Professor of Zoology, Emeritus, Princeton University.
Copeland, Manton, Professor of Biology, Bowdoin College.
Costello, Donald P., Professor of Zoology, University of North Carolina.
Crampton, Henry E., Professor Emeritus, Columbia University.
Croasdale, Hannah T., Technical Assistant, Dartmouth College.
Crouse, Helen V., Research Associate, University of Pennsylvania.
Crowell, Sears, Assistant Professor of Zoology, Miami University.
Froehlich, Alfred, Associate, May Institute for Medical Research.
Furchgott, Robert F., Research Associate, Cornell University.
Furth, Jacob, Professor of Pathology, Cornell University.
Gaffron, Hans, Assistant Professor of Biochemistry, Research Associate, University of Chicago.
Galtsoff, Paul S., Senior Biologist, U. S. Fish and Wildlife Service.
Garrey, W. E., Professor of Physiology, Emeritus, Vanderbilt University, School of Medicine.
Glaser, Otto C., Professor of Biology, Amherst College.
Goodchild, Dr. C. G., Associate Professor of Biology, State Teachers College.
Gorbman, Aubrey, Instructor in Biology, Wayne University.
Gould, Harley N., Professor of Biology, H. Sophie Newcomb College.
Grand, C. G., Research Associate, New York University.
Hamburger, Viktor, Professor of Zoology, Washington University.
Hartman, Frank A., Professor and Chairman of Department of Physiology, Ohio State University.
Harvey, Ethel Browne, Independent Investigator Biology Department, Princeton University.
Harvey, E. Newton, Professor of Physiology, Princeton University.
Hayashi, Teru, Instructor in Zoology, University of Missouri.
Haywood, Charlotte, Professor of Physiology, Mount Holyoke College.
Heilbrunn, L. V., Professor of Zoology, University of Pennsylvania.
Hibbard, Hope, Professor of Zoology, Oberlin College.
Hickson, Anna Keltch, Research Chemist, Eli Lilly & Company.
Hopkins, Hoyt S., Associate Professor of Physiology, New York University, College of Dentistry.
Huber, Wolfgang, Senior Research Chemist, Winthrop Chemical Company.
Jacobs, M. H., Professor of General Physiology, University of Pennsylvania.
Jaeger, Lucena, Research Associate, Columbia University.
Jenkins, George B., Professor of Anatomy, Emeritus, George Washington University.
Johlin, J. M., Associate Professor of Biochemistry, Vanderbilt University.
Johnson, Frank H., Assistant Professor of Biology, Princeton University.
Krahl, M. E., Instructor in Pharmacology, Columbia University.
Landis, Eugene M., Professor of Physiology and Head of Department, Harvard Medical School.

LAVIN, GEORGE I., In charge of Spectroscopic Laboratory, Rockefeller Institute for Medical Research.
LEE, RICHARD E., Student, Columbia University.
LIEBEN, FRITZ, Research Fellow, Johns Hopkins University.
LILLIE, RALPH S., Professor of Physiology, Emeritus, University of Chicago.
LOCHHEAD, JOHN H., Assistant Professor of Zoology, University of Vermont.
McCLUNG, C. E., Professor of Zoology, Emeritus, University of Pennsylvania.
MACLEAN, BERNICE L., Assistant Professor, Department Biological Sciences, Hunter College.
MAGALHAES, HULDA, Instructor in Zoology, Duke University.
MARKS, MILDRED H., Student, Massachusetts Institute of Technology.
MARSLAND, DOUGLAS A., Associate Professor of Biology, New York University.
MAST, S. O., Professor of Zoology, Emeritus, Johns Hopkins University.
MATHEWS, ALBERT P., Professor of Biochemistry, Emeritus, University of Cincinnati.
MATTHEWS, SAMUEL A., Professor of Biology, Williams College.
MEMHARD, ALLEN R., Crescent Road, Riverside, Connecticut.
MENKIN, VALY, Assistant Professor of Pathology, Duke University.
METZ, CHARLES W., Director Zoological Laboratory, University of Pennsylvania.
MICHAELIS, LEONOR, Member Emeritus, Rockefeller Institute for Medical Research.
NACHMANSOHN, DAVID, Research Associate in Neurology, Columbia University.
NORTHROP, JOHN H., Member of the Institute, Rockefeller Institute for Medical Research.
OPPENHEIMER, JANE M., Assistant Professor of Biology, Bryn Mawr College.
OSTERHOUT, W. J. V., Member Emeritus, Rockefeller Institute for Medical Research.
PARPART, ARTHUR K., Associate Professor of Biology, Princeton University.
PIERCE, MADELENE E., Associate Professor of Zoology, Vassar College.
RAMSEY, ROBERT W., Associate Professor of Physiology, Medical College of Virginia.
RANKIN, JOHN S., JR., Assistant Professor of Zoology, University of Connecticut.
REID, W. MALCOLM, Assistant Professor of Biology, Monmouth College.
RIKER, WALTER F., JR., Instructor in Medicine and Pharmacology, Cornell University Medical School.
RIS, HANS, Assistant in Physiology, Rockefeller Institute for Medical Research.
ROBBIE, WILBUR A., Research Associate, State University of Iowa.
ROGICK, MARY DORA, Professor of Biology, College of New Rochelle.
SAMPSON, MYRA M., Professor of Zoology, Smith College.
SANDOW, ALEXANDER, Assistant Professor of Biology, New York University.
SCHAEFFER, A. A., Professor of Biology, Temple University.
SCHARRER, ERNST A., Assistant Professor of Anatomy, Western Reserve University School of Medicine.
SCOTT, SISTER FLORENCE MARIE, Professor of Zoology, Seton Hill College.
SCOTT, GEORGE T., Instructor, Oberlin College.
SHANES, ABRAHAM M., Assistant Professor of Physiology, New York University College of Dentistry.
SHAPIRO, HARRY H., Assistant Professor of Anatomy, Columbia University.
SLIFER, ELEANOR H., Assistant Professor of Zoology, State University of Iowa.
SMITH, DIETRICH CONRAD, Associate Professor of Physiology, University of Maryland, School of Medicine.
STERN, KURT G., Lecturer in Department of Chemistry, Polytechnic Institute of Brooklyn.
STEWART, DOROTHY R., Fellow in Physiology, University of Pennsylvania.
STOKEY, ALMA G., Professor of Plant Science, Emeritus, Mount Holyoke College.
STUNKARD, H. W., Professor of Biology, New York University.
TAFT, CHARLES H., Associate Professor of Pharmacology, Medical Branch, University of Texas.
TAYLOR, WILLIAM RANDOLPH, Professor of Botany, University of Michigan.
TEWINKEL, LOIS E., Associate Professor of Zoology, Smith College.
THIVY, FRANCESCA, Professor of Biology, Women's Christian College.
VILLEE, CLAUDE A., Assistant Professor of Zoology, University of North Carolina.
WAINIO, WALTER W., Assistant Professor of Physiology, New York University, College of Dentistry.
WARREN, CHARLES O., Assistant Professor of Physiology, Cornell University Medical College.
WENRICH, D. H., Professor of Zoology, University of Pennsylvania.
WHITING, ANNA R., Visiting Investigator, University of Pennsylvania.

WHITING, P. W., Associate Professor of Zoology, University of Pennsylvania.
WICHTERMAN, RALPH, Assistant Professor of Biology, Temple University.
WILLIER, B. H., Professor of Zoology and Director of the Biological Laboratories, Johns Hopkins University.
WINSOR, CHARLES P., Research Associate, Princeton University.
WITKUS, ELEANOR R., Instructor in Botany and Bacteriology, Fordham University.
WOODWARD, ALVALYN E., Assistant Professor, University of Michigan.
WOODWARD, ARTHUR A., JR., Research Assistant, University of Pennsylvania.
WOOLEY, D. W., Associate, Rockefeller Institute for Medical Research.
WRINCH, DOROTHY, Lecturer in Physics, Smith College.
YNTEMA, CHESTER L., Assistant Professor of Anatomy, Cornell University Medical College.
ZWEIFACH, BENJAMIN W., Research Associate in Biology, New York University.

Beginning Investigators, 1945

BROWN, ELLEN, Commonwealth Fellow, University of California Medical School.
BROWN, VIRGINIA H., Graduate Student, Ohio State University.
COYNE, CHRISTOPHER J., Student, University of Pennsylvania.
DAVIDSON, MARGARET E., Demonstrator and Assistant to Dr. Berrill, McGill University.
KRUGELIS, EDITH J., Graduate Student, Columbia University.
LERNER, ELEANOR, Fellow in Zoology, Washington University.
LOVELACE, ROBERTA, Teaching Fellow, University of North Carolina.
MILLER, HELMA C., Assistant, Johns Hopkins University.
SCHNEYER, LEON H., Instructor, New York University, College of Dentistry.
WILSON, WALTER, Graduate Student, University of Pennsylvania.

Research Assistants, 1945

ABRAMSKY, TESS, Research Assistant, Rockefeller Institute for Medical Research.
BRUNELLI, ELEANOR L., Research Assistant, New York University, College of Dentistry.
DEFALCO, ROSE H., Research Assistant, University of Pennsylvania.
FISCHL, MATHILDA, Research Assistant in Medicine, Cornell University.
FRANZ, RUTH ESTELLE, Research Assistant, Yale University.
GARZOLI, RAY F., Graduate Student, University of California.
GOULD, DAVID, Research Technician, New York University.
HARLOW, JANET, Technician, Syracuse University.
HELFMAN, MYRNA, Technician, New York University.
HENLEY, CATHERINE, Graduate Teaching Assistant, Johns Hopkins University.
HONEGGER, CAROL, Student, Temple University.
LAWLER, H. CLAIRE, Research Assistant, New York University.
LEVIN, ISAAC, Research Assistant, Princeton University.
LEVY, BETTY, Research Assistant, Rockefeller Institute for Medical Research.
LOOFBOURROW, G. N., Instructor, Rhode Island State College.
MCVEIGH, IDA, Research Assistant in Botany, Yale University.
METZ, DELILAH B., Research Assistant, Eli Lilly & Co.
MINER, KARYL, Research Assistant, New York University.
MITCHELL, CONSTANCE, Research Assistant, University of Pennsylvania.
PETTENGILL, OLIVE S., Student, Temple University.
QUINN, GERTRUDE P., Research Assistant, New York University.
ROTHENBERG, M. A., Research Assistant in Biochemistry, College of Physicians and Surgeons.
UHLMAN, GLORIA E., Research Assistant, Yale University.
WALTERS, C. PATRICIA, Research Assistant, Eli Lilly & Co.
WARNER, CHARLOTTE, Medical Student, University of Pennsylvania.
ZACKS, SUMNER I., Student, Brookline High School.

Library Readers, 1945

AMBERSON, WILLIAM R., Professor of Physiology, University of Maryland.
BECK, LYLE V., Associate Professor of Physiology, Hahnemann Medical College.

BENDICH, AARON, Member War Research Division, Neurological Institute, New York.
BLOCK, RICHARD J., Associate, New York Medical College.
BREHME, KATHERINE S., Lecturer, Cornell University Medical College.
CAHEN, RAYMOND L., Research Assistant, Yale University, Medical School.
CARSON, HAMPTON L., Instructor in Zoology, Washington University.
CASSIDY, HAROLD G., Assistant Professor of Chemistry, Yale University.
COLWIN, LAURA HUNTER, Instructor, Pennsylvania College for Women.
FRIEDEMANN, ULRICH H., Head of Department of Bacteriology, Brooklyn Jewish Hospital.
FRISCH, JOHN A., Professor of Biology, Canisius College.
GATES, R. RUGGLES, Professor Emeritus, University of London.
GUREWICH, VLADIMIR, Assistant Visiting Physician, Bellevue Hospital.
KABAT, ELVIN A., Research Associate in Biochemistry, College of Physicians and Surgeons.
KAYLOR, CORNELIUS T., Assistant Professor of Anatomy, Syracuse University.
KELLER, RUDOLPH, Researcher, Robinson Foundation, New York.
KRASNOW, FRANCES, Head of Department of Research, Guggenheim Dental Foundation.
LANGE, MATHILDE M., Professor of Zoology, Head of Department of Biology, Wheaton College.
LOEWI, OTTO, Research Professor of Pharmacology, New York University, College of Medicine.
MARINELLI, LEONIDAS, Physicist, Memorial Hospital.
MAVOR, JAMES W., Professor of Biology, Union College.
MAYER, MANFRED M., Scientific Staff, War Research Division, Columbia University.
METZ, CHARLES B., Instructor in Biology, Wesleyan University.
MEYERHOF, DR. OTTO, Research Professor of Biochemistry, University of Pennsylvania.
MOLDAVER, JOSEPH, Research Associate in Neurology, Columbia University.
MOORE, JOHN A., Assistant Professor of Zoology, Barnard College.
MOSCHCOWITZ, ELI, Assistant Professor of Chemical Medicine, Columbia University.
OSEASOHN, ROBERT O., Long Island College of Medicine.
PERRY, BARBARA H., Graduate Student and Teaching Fellow in Zoology, Smith College.
PONDER, ERIC, Research, Nassau Hospital.
RAMSDEN, ETHEL J., Instructor in Biology, Montclair Teachers College.
ROBINSON, MILES H., Instructor in Pharmacology, University of Pennsylvania.
RYAN, FRANCIS J., Assistant Professor, Columbia University.
SCOTT, ALLAN, Assistant Professor of Biology, Union College.
STRAUSS, WILLIAM L., JR., Associate Professor of Anatomy, Johns Hopkins University.
VONDACH, HERMAN, Assistant Professor of Physiology, Georgetown Medical School.
WALLACH, JACQUES B., Long Island College of Medicine.
ZORZOLI, ANITA, Assistant Instructor, New York University.

Students, 1945

BOTANY

BARRACLOUGH, MARY EDITH, Student, Smith College.
DIETZ, ALMA, Assistant in Biology, American International College.
GARDNER, ELIZABETH B., Radcliffe College.
MOUL, EDWIN THEODORE, Botany Assistant, University of Pennsylvania.
SMITH, MATTIE LOU, Student, Radcliffe College.

EMBRYOLOGY

BEACH, JANET, Student, University of Connecticut.
BERNIER, GERMAINE, University of Montreal, Quebec, Canada.
BERRY, BETH SINCLAIR, Student, Rockford College, Illinois.
CARTER, MARJORIE ESTELLE, Teacher, Georgia State Women's College.
CHIRICO, ANNA MARIE, Student, Seton Hill College.
CLARK, CARL CYRUS, Student, Amherst College.
COPINGER, ANNE STEVENS, Goucher College.
EHRLICH, MIRIAM, Knox College.
IZZO, MARY JANE, University of Rochester.
KELL, AMY, University of Illinois.
LEVIN, ILANE B., Goucher College.

Lodico, Dorothy Geraldine, University of Rochester.
Lovelace, Lollie Roberta, Teaching Fellow, University of North Carolina.
Marker, Muriel Josephine, Student, Colby College.
Mezger, Liselotte, Student, Bryn Mawr College.
Miller, Helma C., Graduate Assistant, Johns Hopkins University.
Perkins, Barbara Burnham, University of Connecticut.
Raymond, Barbara, Student, Swarthmore College.
Rice, Mary Esther, Assistant in Biology Laboratory, Drew University.
Roberts, Elizabeth S., Assistant in Biology, Wilson College.
Ruderman, Claire, Teaching Assistant, University of Rochester.
Thorby, Jean Adelaide, Student, Rockford College.
Uphoff, Delta E., University of Rochester.

PHYSIOLOGY

Brust, Manfred, Student, New York University.
Cook, John Alfred, George Washington University.
Ferguson, Alice Howard, Graduate Assistant, Louisiana State University.
Flinker, Marie-Louise M., Assistant in Physiology, Vassar College.
Fogerson, Virginia Lee, Student, Drury College.
Foster, Elizabeth Jane, Student, University of Illinois.
Goldsmith, Yvette, Perth Amboy, New Jersey.
Hajek, Norma Mary, Cornell University.
Hecht, Liselotte Isabella, Student, University of Michigan.
Resnick, Oscar, Resident Scholar, Harvard University.
Weiss, Michael S., Student, Washington Square College.
Wolff, Mary Lyda, Instructor, Cedar Crest College.
Worken, Barney, 3400 Wayne Avenue, New York City.

ZOOLOGY

Aronowitz, Olga, New York University.
Bates, Mary Florence, Student, Vassar College.
Bayors, Winifred M., Student Seton Hill College.
Beal, Judith D., Vassar College.
Benjamin, Mrs. Rezsin C., Undergraduate Student, University of Rochester.
Bernard, Sister Marie, Fordham University.
Bernier, Germaine, Instructor, University of Montreal.
Bezilla, Helen, Student, Seton Hill College.
Bradin, John L., Northwestern University.
Calvert, Julie Neil, Student, Wilson College.
Carlson, Alice Marie, Laboratory Assistant, University of Minnesota.
Chaffin, Evelyn L., Student, Drury College.
Clark, Carl Cyrus, Amherst College.
Cummings, Rev. George W., Graduate Student, Catholic University.
Dailey, Dorothy Helen, Depauw University.
Dawson, Mary Jean, Student, Mt. Holyoke College.
Dempsey, Ellen, Oberlin College.
Dickason, Mary Elizabeth, Student, Smith College.
Farnham, Carol Jean, Student, Drury College.
Freitag, Janet Faith, Student, University of Connecticut.
Goldis, Bernice Ruth, Graduate Student, University of Pennsylvania.
Hanlon, Rev. James J., Graduate Student, Fordham University.
Hill, Shirley B., Student, Vassar College.
Hines, Eileen Barbara, State University of Iowa.
Jones, Dorothy B., Student, University of Connecticut.
Josita, Sister M., Student, Fordham University.
Julier, Edith Vaillant, Student, Vassar College.

KREKELER, CARL H., Student, Washington University.
KUHN, ALICE ROBERTS, Western-Maryland College.
LOWENS, MARY DOROTHY, Student, Swarthmore College.
MCCLAIN, MARYLOW, Student, Swarthmore College.
MCGREGOR, ELIZABETH, Instructor, Mount Holyoke College.
MCVICKER, SISTER MAUREEN, Teacher of Biology, St. Joseph's College for Women.
MALLOCH, JEAN, Vassar College.
MEIHACK, HELEN LLOYD, Student, Oberlin College.
MINA, FRANK A., Laboratory Instructor, Fordham University.
OSBORN, JOAN A., Student, Barnard College.
PETERS, REV. JOSEPH J., Graduate Student, Fordham University.
RAYMOND, BARBARA, Student, Swarthmore College.
RIGGS, AUSTIN F., Student, Harvard University.
ROGERS, HENRY CRAMPTON, Deerfield Academy.
SCHAEFER, GERTRUDE, Undergraduate, Temple University.
SEAMAN, ARLENE, Zoology Assistant, Cornell University.
SNIPES, ANNE, Wheaton College.
STEES, NANCY, Teacher, West Chester State Teachers College.
SURRARRER, THOMAS C., Professor of Biology, Baldwin-Wallace College.
THORNTON, DOROTHY GOLDEN, Assistant in Zoology Dept., Wellesley College.
TUPPER, LYLA, Graduate Student, Northwestern University.
UBER, VIRGINIA M., Student, Pennsylvania College for Women.
WAX, FLORENCE SIMA, Student, Oberlin College.
WHYTE, MARJORIE ANN, Assistant, Cornell University.
WILCOX, BARBARA L., Student, Radcliffe College.
WILLIAMS, OLWEN, Teacher of Biology and Chemistry, The Putney School.
WILSON, FAITH EVELYN, Johns Hopkins University.
WILSON, MARIE ELLEN, Student, Western Maryland College.

4. TABULAR VIEW OF ATTENDANCE

	1941	*1942*	*1943*	*1944*	*1945*
INVESTIGATORS—Total	337	201	160	193	212
Independent	197	132	89	112	138
Under instruction	59	16	19	11	10
Library readers	31	28	35	50	38
Research assistants	50	25	17	20	26
STUDENTS—Total	131	74	68	75	96
Zoology	55	36	47	37	55
Embryology	37	24	13	23	23
Physiology	24	6	8	10	13
Botany	15	8	—	5	5
TOTAL ATTENDANCE	468	275	228	276	308
Less persons registered as both students and investigators	7	2	6	1	
	461	273	222	275	
INSTITUTIONS REPRESENTED—Total	144	126	116	106	124
By investigators	102	83	70	74	100
By students	72	43	41	41	49
SCHOOLS AND ACADEMIES REPRESENTED					
By investigators	5	2	2	1	2
By students	2	—	1	2	2
FOREIGN INSTITUTIONS REPRESENTED					
By investigators	3	—	2	2	1
By students	1	—	—	3	—

5. Subscribing and Cooperating Institutions

1945

Albany Medical College
Amherst College
Biological Institute, Philadelphia, Pennsylvania
Bowdoin College
Bryn Mawr College
Cathedral College
The Catholic University of America
Columbia University
Cornell University
Cornell University Medical College
Duke University
Fish and Wild Life Service, U. S. Dept. of the Interior
Fordham University
Goucher College
Harvard University
Harvard University Medical School
Industrial and Engineering Chemistry, of the American Chemical Society
Johns Hopkins University
Johns Hopkins Medical School
Lee Foundation
Eli Lilly & Company
Long Island University
Macy Foundation
Massachusetts Institute of Technology
McGill University
Miami University
Mount Holyoke College
New York University
New York University College of Medicine
New York University School of Dentistry
New York University Washington Square College
Oberlin College
Ohio State University
Pennsylvania College for Women
Princeton University
Radcliffe College
Rockefeller Institute for Medical Research
St. Joseph College for Women
Smith College
State University of Iowa
Syracuse University
Syracuse University Medical School
Temple University
University of Chicago
University of Connecticut
University of Illinois
University of Maryland Medical School
University of Michigan
University of Missouri
University of Pennsylvania
University of Pennsylvania School of Medicine
University of Rochester
Vanderbilt University Medical School
Vassar College
Washington University
Wayne University
Wellesley College
Wesleyan University
Western Maryland College
Western Reserve University
Wheaton College
Williams College
Wilson College
Woods Hole Oceanographic Institution
Yale University

6. Evening Lectures, 1945

Friday, June 29
Prof. P. W. Whiting ..... "The Development of Hymenopteran Genetics."

Friday, July 6
Dr. R. R. Gates ..... "Human Heredity in Relation to Animal Genetics."

Friday, July 13
Dr. I. Fankuchen ..... "X-Ray Diffraction and Protein Structure."

Friday, July 20
Prof. S. C. Brooks ..... "Our Interrelationships with South American Universities, together with Illustrated Travel Notes."

Friday, July 27
Prof. E. G. Butler ..... "Problems of Differentiation and Dedifferentiation in Amputated Urodele Limbs."

Friday, August 3
Dr. Bostwick H. Ketchum ....."The Prevention of Ship Bottom Fouling."

Friday, August 10
Dr. Daniel Merriman ....."A Study in Pure and Applied Marine Biology. The Life History and Economic Importance of the Ocean Pout."

Friday, August 17
Dr. Detlev W. Bronk ....."Biological Research During the War and Postwar Periods."

Friday, August 24
Dr. F. L. Hisaw ....."Endocrines and the Evolution of Viviparity among the Vertebrates."

Monday, August 27
George G. Lower ....."Local Invertebrates."

Wednesday, August 29
Dr. Paul S. Galtsoff ....."Impressions of a Biologist at the San Francisco Conference."

Thursday, August 30
Major A. H. Neufeld ....."Medical Research Organization in the Canadian Army."

Thursday, August 30
Capt. W. R. Duryee ....."Medical Military Training."

7. Shorter Scientific Papers, 1945

Tuesday, July 24
Dr. M. M. Brooks ....."The Redox Potential of Penicillium rotatum Medium under Some Different Conditions of Growth."
Dr. Wilbur Robbie ....."The Use of Cyanide in Manometric Experimentation."
Dr. Sears Crowell ....."The Displacement of Terns by Gulls at Weepecket Island."

Tuesday, July 31
Dr. P. W. Whiting ....."The Problem of Reversal of Male Haploidy by Selection."
Dr. Berta Scharrer ....."Experimental Tumors after Nerve Section in an Insect."
Dr. P. S. Galtsoff ....."Reactions of Oysters to Free Chlorine."

Tuesday, August 7
Dr. T. H. Bullock ....."Organization of Giant Nerve Fibers in certain Polychaetes."
Dr. Ernst Scharrer ....."The Origin of Neurosecretory Granules from Basophil Substances in the Nerve Cells of Fishes."
Dr. C. H. Taft ....."The Action of Quitenine on the Livers of Tautog and Toadfish."
Dr. A. M. Shanes ....."Evidence of a Metabolic Effect by Potassium in Lowering the Injury Potential of Nerve."

Tuesday, August 14

DR. R. CHAMBERS ..... "Interrelations between Sperm-Nucleus, Egg-Nucleus and Cytoplasm in Asterias Egg."

DR. KURT G. STERN ..... "Physical-chemical Studies on Chromosomal Nucleoproteins."

Tuesday, August 21

DR. DOROTHY WRINCH ..... "Hemoglobin and other Native Proteins."

DR. E. R. WITKUS ..... "Endomitosis in Plants."

DR. C. A. BERGER ..... "Recent Cytological Studies in Culex."

Thursday, August 23

DR. ETHEL B. HARVEY ..... "Development of Granule-free Fractions of Arbacia eggs."

DR. ALEXANDER SANDOW ..... "Studies of the Muscle Twitch by Methods of Electronic Recording."

DR. C. D. BEERS ..... "The Role of Bacteria in the Excystment of the Ciliate Didinium."

Monday, August 27

DR. ANNA R. WHITING ..... "Differences in Sensitivity, Hatchability Curves and Cytological Effects between Eggs X-rayed in First Meiotic Prophase and Metaphase."

DR. W. W. WAINIO ..... "Aerobic Oxidation of Simple sugars by Mammalian Liver."

DR. DUGALD E. S. BROWN ..... "The Role of Myosin and Myosin Triphosphatase *in Vitro* and in Muscle."

Tuesday, August 28

DR. LLOYD M. BERTHOLF ..... "Accelerating Metamorphosis in the Tunicate Styela."

DR. ALFRED FROELICH ..... "The Influence of Drugs on Heat-narcosis."

DR. W. MALCOLM REID ..... "*In Vivo* and *in Vitro* Glycogen Utilization in the Avial Nematode Ascardia Galli."

8. MEMBERS OF THE CORPORATION, 1945

1. LIFE MEMBERS

ALLIS, MR. E. P., JR., Palais Carnoles, Menton, France.
BECKWITH, DR. CORA J., Vassar College, Poughkeepsie, New York.
BILLINGS, MR. R. C., 66 Franklin Street, Boston, Massachusetts.
CALVERT, DR. PHILIP P., University of Pennsylvania, Philadelphia, Pennsylvania.
COLE, DR. LEON J., College of Agriculture, Madison, Wisconsin.
CONKLIN, PROF. EDWIN G., Princeton University, Princeton, New Jersey.
COWDRY, DR. E. V., Washington University, St. Louis, Missouri.
JACKSON, MR. CHAS. C., 24 Congress Street, Boston, Massachusetts.
JACKSON, MISS M. C., 88 Marlboro Street, Boston, Massachusetts.
KING, MR. CHAS. A.

KINGSBURY, PROF. B. F., Cornell University, Ithaca, New York.
LEWIS, PROF. W. H., Johns Hopkins University, Baltimore, Maryland.
MEANS, DR. J. H., 15 Chestnut Street, Boston, Massachusetts.
MOORE, DR. GEORGE T., Missouri Botanical Gardens, St. Louis, Missouri.
MOORE, DR. J. PERCY, University of Pennsylvania, Philadelphia, Pa.
MORGAN, MRS. T. H., Pasadena, California.
MORGAN, PROF. T. H., Director of Biological Laboratory, California Institute of Technology, Pasadena, California.
NOYES, MISS EVA J.
PORTER, DR. H. C., University of Pennsylvania, Philadelphia, Pennsylvania.
SCOTT, DR. ERNEST L., Columbia University, New York City, New York.
SEARS, DR. HENRY F., 86 Beacon Street, Boston, Massachusetts.
SHEDD, MR. E. A.
STRONG, DR. O. S., Columbia University, New York City, New York.
WAITE, PROF. F. C., 144 Locust Street, Dover, New Hampshire.
WALLACE, LOUISE B., 359 Lytton Avenue, Palo Alto, California.

2. REGULAR MEMBERS

ADAMS, DR. A. ELIZABETH, Mount Holyoke College, South Hadley, Massachusetts.
ADDISON, DR. W. H. F., University of Pennsylvania Medical School, Philadelphia, Pennsylvania.
ADOLPH, DR. EDWARD F., University of Rochester Medical School, Rochester, New York.
ALBAUM, DR. HARRY G., Biology Dept., Brooklyn College, Brooklyn, N. Y.
ALBERT, DR. ALEXANDER, 383 Harvard Street, Cambridge, Mass.
ALLEE, DR. W. C., The University of Chicago, Chicago, Illinois.
AMBERSON, DR. WILLIAM R., Department of Physiology, University of Maryland, School of Medicine, Lombard and Greene Streets, Baltimore, Maryland.
ANDERSON, DR. RUBERT S., University of Maryland School of Medicine, Department of Physiology, Baltimore, Maryland.
ANDERSON, DR. T. F., University of Pennsylvania, Philadelphia, Pennsylvania.
ARMSTRONG, DR. PHILIP B., College of Medicine, Syracuse University, Syracuse, New York.
AUSTIN, DR. MARY L., Wellesley College, Wellesley, Massachusetts.
BAITSELL, DR. GEORGE A., Yale University, New Haven, Connecticut.
BAKER, DR. H. B., Zoological Laboratory, University of Pennsylvania, Philadelphia, Pennsylvania.
BALLARD, DR. WILLIAM W., Dartmouth College, Hanover, New Hampshire.
BALLENTINE, DR. ROBERT, Columbia University, Department of Zoology, New York City, New York.
BALL, DR. ERIC G., Department of Biological Chemistry, Harvard University Medical School, Boston, Massachusetts.
BARD, PROF. PHILIP, Johns Hopkins Medical School, Baltimore, Maryland.
BARRON, DR. E. S. GUZMAN, Department of Medicine, The University of Chicago, Chicago, Illinois.
BARTH, DR. L. G., Department of Zoology, Columbia University, New York City, New York.

BARTLETT, DR. JAMES H., Department of Physics, University of Illinois, Urbana, Illinois.
BEADLE, DR. G. W., School of Biological Sciences, Stanford University, California.
BEAMS, DR. HAROLD W., Department of Zoology, State University of Iowa, Iowa City, Iowa.
BECK, DR. L. V., Hahnemann Medical College, Philadelphia, Pennsylvania.
BEHRE, DR. ELINOR H., Louisiana State University, Baton Rouge, Louisiana.
BERTHOLF, DR. LLOYD M., Western Maryland College, Westminster, Maryland.
BIGELOW, DR. H. B., Museum of Comparative Zoology, Cambridge, Massachusetts.
BIGELOW, PROF. R. P., Massachusetts Institute of Technology, Cambridge, Massachusetts.
BINFORD, PROF. RAYMOND, Guilford College, North Carolina.
BISSONNETTE, DR. T. HUME, Trinity College, Hartford, Connecticut.
BLANCHARD, PROF. K. C., Johns Hopkins Medical School, Baltimore, Maryland.
BODINE, DR. J. H., Department of Zoology, State University of Iowa, Iowa City, Iowa.
BORING, DR. ALICE M., Dickinson House, South Hadley, Massachusetts.
BRADLEY, PROF. HAROLD C., University of Wisconsin, Madison, Wisconsin.
BRODIE, MR. DONALD M., 522 Fifth Avenue, New York City, New York.
BRONFENBRENNER, DR. JACQUES J., Department of Bacteriology, Washington University Medical School, St. Louis, Missouri.
BROOKS, DR. MATILDA M., University of California, Department of Zoology, Berkeley, California.
BROOKS, DR. S. C., University of California, Berkeley, California.
BROWN, DR. DUGALD E. S., New York University, College of Dentistry, 209 East 23d Street, New York City, New York.
BROWN, DR. FRANK A., JR., Department of Zoology, Northwestern University, Evanston, Illinois.
BUCK, DR. JOHN B., Industrial Hygiene Research Lab., National Institute of Health, Bethesda, Maryland.
BUCKINGHAM, MISS EDITH N., Sudbury, Massachusetts.
BUDINGTON, PROF. R. A., Winter Park, Florida.
BULLINGTON, DR. W. E., Randolph-Macon College, Ashland, Virginia.
BULLOCK, DR. T. L., University of Missouri, Columbia, Missouri.
BURBANCK, DR. WILLIAM D., Department of Biology, Drury College, Springfield, Missouri.
BURKENROAD, DR. M. D., Yale University, New Haven, Connecticut.
BUTLER, DR. E. G., Princeton University, Princeton, N. J.
BYRNES, DR. ESTHER F., 1803 North Camac Street, Philadelphia, Pennsylvania.
CAMERON, DR. J. A., Baylor College of Dentistry, Dallas, Texas.
CANNAN, PROF. R. K., New York University College of Medicine, 477 First Avenue, New York City, New York.
CARLSON, PROF. A. J., Department of Physiology, The University of Chicago, Chicago, Illinois.
CAROTHERS, DR. E. ELEANOR, 134 Avenue C. East, Kingman, Kansas.
CARPENTER, DR. RUSSELL L., Tufts College, Tufts College, Massachusetts.
CARROLL, PROF. MITCHELL, Franklin and Marshall College, Lancaster, Pennsylvania.

CARVER, PROF. GAIL L., Mercer University, Macon, Georgia.
CATTELL, DR. MCKEEN, Cornell University Medical College, 1300 York Avenue, New York City, New York.
CATTELL, MR. WARE, 1621 Connecticut Ave., Washington, D. C.
CHAMBERS, DR. ROBERT, Washington Square College, New York University, Washington Square, New York City, New York.
CHASE, DR. AURIN M., Princeton University, Princeton, New Jersey.
CHENEY, DR. RALPH H., Biology Department, Long Island University, Brooklyn, New York.
CHIDESTER, PROF. F. E., Auburndale, Massachusetts.
CHILD, PROF. C. M., Jordan Hall, Stanford University, California.
CHURNEY, DR. LEON, 155 Powell Lane, Upper Darby, Pennsylvania.
CLAFF, MR. C. LLOYD, Research Fellow in Surgery, Harvard Medical School, Boston, Mass.
CLARK, PROF. E. R., University of Pennsylvania Medical School, Philadelphia, Pennsylvania.
CLARK, DR. LEONARD B., Department of Biology, Union College, Schenectady, New York.
CLARKE, DR. G. L., Harvard University Biol. Lab., 16 Divinity Ave., Cambridge 38, Mass.
CLELAND, PROF. RALPH E., Indiana University, Bloomington, Indiana.
CLOWES, DR. G. H. A., Eli Lilly and Company, Indianapolis, Indiana.
COE, PROF. W. R., Yale University, New Haven, Connecticut.
COHN, DR. EDWIN J., 183 Brattle Street, Cambridge, Massachusetts.
COLE, DR. ELBERT C., Department of Biology, Williams College, Williamstown, Massachusetts.
COLE, DR. KENNETH S., University of Chicago, Chicago, Illinois.
COLLETT, DR. MARY E., Western Reserve University, Cleveland, Ohio.
COLTON, PROF. H. S., Box 601, Flagstaff, Arizona.
COOPER, DR. KENNETH W., Department of Biology, Princeton University, Princeton, New Jersey.
COPELAND, PROF. MANTON, Bowdoin College, Brunswick, Maine.
COSTELLO, DR. DONALD P., Department of Zoology, University of North Carolina, Chapel Hill, North Carolina.
COSTELLO, DR. HELEN MILLER, Department of Zoology, University of North Carolina, Chapel Hill, North Carolina.
CRAMPTON, PROF. H. E., American Museum of Natural History, New York City, New York.
CRANE, JOHN O., Woods Hole, Massachusetts.
CRANE, MRS. W. MURRAY, Woods Hole, Massachusetts.
CROASDALE, HANNAH T., Dartmouth College, Hanover, New Hampshire.
CROUSE, DR. HELEN V., University of Pennsylvania, Philadelphia, Pennsylvania.
CROWELL, DR. P. S., JR., Department of Zoology, Miami University, Oxford, Ohio.
CURTIS, DR. MAYNIE R., 377 Dexter Trail, Mason, Michigan.
CURTIS, PROF. W. C., University of Missouri, Columbia, Missouri.
DAN, DR. KATSUMA, Misaki Biological Station, Misaki, Japan.
DAVIS, DR. DONALD W., College of William and Mary, Williamsburg, Virginia.
DAWSON, DR. A. B., Harvard University, Cambridge, Massachusetts.

DAWSON, DR. J. A., The College of the City of New York, New York City, New York.
DEDERER, DR. PAULINE H., Connecticut College, New London, Connecticut.
DEMEREC, DR. M., Carnegie Institution of Washington, Cold Spring Harbor, Long Island, New York.
DILLER, DR. WILLIAM F., 1016 South 45th Street, Philadelphia, Pennsylvania.
DODDS, PROF. G. S., Medical School, University of West Virginia, Morgantown West Virginia.
DOLLEY, PROF. WILLIAM L., University of Buffalo, Buffalo, New York.
DONALDSON, DR. JOHN C., University of Pittsburgh, School of Medicine, Pittsburgh, Pennsylvania.
DUBOIS, DR. EUGENE F., Cornell University Medical College, 1300 York Avenue, New York City, New York.
DUGGAR, DR. BENJAMIN M., c/o Lederle Laboratories Inc., Pearl River, New York.
DUNGAY, DR. NEIL S., Carleton College, Northfield, Minnesota.
DURYEE, DR. WILLIAM R., Surgeon General's Office, Washington, D. C.
EDWARDS, DR. D. J., Cornell University Medical College, 1300 York Avenue, New York City, New York.
ELLIS, DR. F. W., 1175 Centre Street, Newton, Massachusetts.
EVANS, DR. TITUS C., College of Physicians and Surgeons, 630 West 168th Street, New York City, New York.
FAILLA, DR. G., College of Physicians and Surgeons, 630 West 168th Street, New York City, New York.
FAURÉ-FREMIET, PROF. EMMANUEL, Collège de France, Paris, France.
FAUST, DR. ERNEST C., Tulane University of Louisiana, New Orleans, Louisiana.
FERGUSON, DR. JAMES K. W., Department of Pharmacology, University of Toronto, Ontario, Canada.
FIGGE, DR. F. H. J., 4636 Schenley Road, Baltimore, Maryland.
FISCHER, DR. ERNST, Department of Physiology, Medical College of Virginia, Richmond, Virginia.
FISHER, DR. JEANNE M., Department of Biochemistry, University of Toronto, Toronto, Canada.
FISHER, DR. KENNETH C., Department of Biology, University of Toronto, Toronto, Canada.
FORBES, DR. ALEXANDER, Harvard University Medical School, Boston, Massachusetts.
FRISCH, DR. JOHN A., Canisius College, Buffalo, New York.
FURTH, DR. JACOB, Cornell University Medical College, 1300 York Avenue, New York City, New York.
GALTSOFF, DR. PAUL S., 420 Cumberland Avenue, Somerset, Chevy Chase, Maryland.
GARREY, PROF. W. E., Vanderbilt University Medical School, Nashville, Tennessee.
GATES, DR. REGINALD R., Woods Hole, Massachusetts.
GEISER, DR. S. W., Southern Methodist University, Dallas, Texas.
GERARD, PROF. R. W., The University of Chicago, Chicago, Illinois.
GLASER, PROF. O. C., Amherst College, Amherst, Massachusetts.

GOLDFORB, PROF. A. J., College of the City of New York, Convent Avenue and 139th Street, New York City, New York.
GOODCHILD, DR. CHAUNCEY G., State Teachers College, Springfield, Missouri.
GOODRICH, PROF. H. B., Wesleyan University, Middletown, Connecticut.
GOTTSCHALL, DR. GERTRUDE Y., 919 20th Street, Washington, D. C.
GRAHAM, DR. J. Y., Roberts, Wisconsin.
GRAND, CONSTANTINE G., Biology Department, Washington Square College, New York University, Washington Square, New York City, New York.
GRAVE, PROF. B. H., DePauw University, Greencastle, Indiana.
GRAY, PROF. IRVING E., Duke University, Durham, North Carolina.
GREGORY, DR. LOUISE H., Barnard College, Columbia University, New York City, New York.
GUDERNATSCH, DR. J. FREDERICK, New York University, 100 Washington Square, New York City, New York.
GUTHRIE, DR. MARY J., University of Missouri, Columbia, Missouri.
GUYER, PROF. M. F., University of Wisconsin, Madison, Wisconsin.
HAGUE, DR. FLORENCE, Sweet Briar College, Sweet Briar, Virginia.
HALL, PROF. FRANK G., Duke University, Durham, North Carolina.
HAMBURGER, DR. VIKTOR, Department of Zoology, Washington University, St. Louis, Missouri.
HANCE, DR. ROBERT T., The Cincinnati Milling Machine Co., Cincinnati 9, Ohio.
HARGITT, PROF. GEORGE T., Department of Zoology, Duke University, Durham, North Carolina.
HARMAN, DR. MARY T., Kansas State Agricultural College, Manhattan, Kansas.
HARNLY, DR. MORRIS H., Washington Square College, New York University, New York City, New York.
HARPER, PROF. R. A., R. No. 5, Bedford, Virginia.
HARRISON, PROF. ROSS G., Yale University, New Haven, Connecticut.
HARTLINE, DR. H. KEFFER, University of Pennsylvania, Philadelphia, Pennsylvania.
HARTMAN, DR. FRANK A., Hamilton Hall, Ohio State University, Columbus, Ohio.
HARVEY, DR. E. NEWTON, Guyot Hall, Princeton University, Princeton, New Jersey.
HARVEY, DR. ETHEL BROWNE, 48 Cleveland Lane, Princeton, New Jersey.
HAYDEN, DR. MARGARET A., Wellesley College, Wellesley, Massachusetts.
HAYES, DR. FREDERICK R., Zoological Laboratory, Dalhousie University, Halifax, Nova Scotia.
HAYWOOD, DR. CHARLOTTE, Mount Holyoke College, South Hadley, Massachusetts.
HECHT, DR. SELIG, Columbia University, New York City, New York.
HEILBRUNN, DR. L. V., Department of Zoology, University of Pennsylvania, Philadelphia, Pennsylvania.
HENDEE, DR. ESTHER CRISSEY, Russell Sage College, Troy, New York.
HENSHAW, DR. PAUL S., National Cancer Institute, Bethesda, Maryland.
HESS, PROF. WALTER N., Hamilton College, Clinton, New York.
HIATT, DR. E. P., Duke University, Durham, North Carolina.
HIBBARD, DR. HOPE, Department of Zoology, Oberlin College, Oberlin, Ohio.
HILL, DR. SAMUEL E., 18 Collins Avenue, Troy, New York.
HINRICHS, DR. MARIE, Department of Physiology and Health Education, Southern Illinois Normal University, Carbondale, Illinois.

HISAW, DR. F. L., Harvard University, Cambridge, Massachusetts.
HOADLEY, DR. LEIGH, Harvard University, Cambridge, Massachusetts.
HÖBER, DR. RUDOLF, University of Pennsylvania, Philadelphia, Pennsylvania.
HODGE, DR. CHARLES, IV, Temple University, Department of Zoology, Philadelphia, Pennsylvania.
HOGUE, DR. MARY J., University of Pennsylvania Medical School, Philadelphia, Pennsylvania.
HOLLAENDER, DR. ALEXANDER, c/o National Institute of Health, Laboratory of Industrial Hygiene, Bethesda, Maryland.
HOPKINS, DR. DWIGHT L., Mundelein College, 6363 Sheridan Road, Chicago, Illinois.
HOPKINS, DR. HOYT S., New York University, College of Dentistry, New York City, New York.
HOWLAND, DR. RUTH B., Washington Square College, New York University, Washington Square East, New York City, New York.
HOYT, DR. WILLIAM D., Washington and Lee University, Lexington, Virginia.
HYMAN, DR. LIBBIE H., American Museum of Natural History, New York City, New York.
IRVING, LT. COL. LAURENCE, Wright Field, Dayton, Ohio.
ISELIN, MR. COLUMBUS O'D., Woods Hole, Massachusetts.
JACOBS, PROF. MERKEL H., School of Medicine, University of Pennsylvania, Philadelphia, Pennsylvania.
JENKINS, DR. GEORGE B., 1336 Parkwood Place, N.W., Washington, D. C.
JENNINGS, PROF. H. S., Department of Zoology, University of California, Los Angeles, California.
JOHLIN, DR. J. M., Vanderbilt University Medical School, Nashville, Tennessee.
JONES, DR. E. RUFFIN, JR., College of William and Mary, Williamsburg, Virginia.
KAUFMANN, PROF. B. P., Carnegie Institution, Cold Spring Harbor, Long Island, New York.
KEMPTON, PROF. RUDOLF T., Vassar College, Poughkeepsie, New York.
KIDDER, DR. GEORGE W., Brown University, Providence, Rhode Island.
KIDDER, JEROME F., Woods Hole, Massachusetts.
KILLE, DR. FRANK R., Carleton College, Northfield, Minnesota.
KINDRED, DR. J. E., University of Virginia, Charlottesville, Virginia.
KING, DR. HELEN D., Wistar Institute of Anatomy and Biology, 36th Street and Woodland Avenue, Philadelphia, Pennsylvania.
KING, DR. ROBERT L., State University of Iowa, Iowa City, Iowa.
KNOWLTON, PROF. F. P., Syracuse University, Syracuse, New York.
KOPAC, DR. M. J., Washington Square College, New York University, New York City, New York.
KRAHL, DR. M. E., College of Physicians and Surgeons, 630 West 168th Street, New York 32, New York.
KRIEG, DR. WENDELL J. S., 303 East Chicago Ave., Chicago, Illinois.
LANCEFIELD, DR. D. E., Queens College, Flushing, New York.
LANCEFIELD, DR. REBECCA C., Rockefeller Institute, 66th Street and York Avenue, New York City, New York.
LANDIS, DR. E. M., Harvard Medical School, Boston, Massachusetts.
LANGE, DR. MATHILDE M., Wheaton College, Norton, Massachusetts.

LAVIN, DR. GEORGE I., Rockefeller Institute, 66th Street and York Avenue, New York City, New York.
LEWIS, PROF. I. F., University of Virginia, Charlottesville, Virginia.
LILLIE, PROF. FRANK R., The University of Chicago, Chicago, Illinois.
LILLIE, PROF. RALPH S., The University of Chicago, Chicago, Illinois.
LITTLE, DR. E. P., Phillips Exeter Academy, Exeter, New Hampshire.
LOCHHEAD, DR. JOHN H., Department of Zoology, University of Vermont, Burlington, Vermont.
LOEB, PROF. LEO, 40 Crestwood Drive, St. Louis, Missouri.
LOEB, DR. R. F., 180 Ft. Washington Avenue, New York City, New York.
LOEWI, PROF. OTTO, 155 East 93d Street, New York City, New York.
LOWTHER, MRS. FLORENCE DEL., Barnard College, Columbia University, New York City, New York.
LUCAS, DR. ALFRED M., Regional Poultry Research Laboratory, East Lansing, Michigan.
LUCKÉ, PROF. BALDUIN, University of Pennsylvania, Philadelphia, Pennsylvania.
LYNCH, DR. CLARA J., Rockefeller Institute, 66th Street and York Avenue, New York City, New York.
LYNCH, DR. RUTH STOCKING, Dept. of Zoology, University of California, Los Angeles 24, California.
LYNN, DR. WILLIAM G., Department of Biology, The Catholic University of America, Washington, D. C.
MACDOUGALL, DR. MARY S., Agnes Scott College, Decatur, Georgia.
MACNAUGHT, MR. FRANK M., Marine Biological Laboratory, Woods Hole, Massachusetts.
MCCOUCH, DR. MARGARET SUMWALT, University of Pennsylvania Medical School, Philadelphia, Pa.
MCGREGOR, DR. J. H., Columbia University, New York City, New York.
MACKLIN, DR. CHARLES C., School of Medicine, University of Western Ontario, London, Canada.
MAGRUDER, DR. SAMUEL R., Department of Anatomy, Tufts Medical School, Boston, Massachusetts.
MALONE, PROF. E. F., 153 Cortland Avenue, Winter Park, Florida.
MANWELL, DR. REGINALD D., Syracuse University, Syracuse, New York.
MARSLAND, DR. DOUGLAS A., Washington Square College, New York University, New York City, New York.
MARTIN, PROF. E. A., Department of Biology, Brooklyn College, Bedford Avenue and Avenue H, Brooklyn, New York.
MAST, PROF. S. O., Johns Hopkins University, Baltimore, Maryland.
MATHEWS, PROF. A. P., Woods Hole, Massachusetts.
MATTHEWS, DR. SAMUEL A., Thompson Biological Laboratory, Williams College, Williamstown, Massachusetts.
MAVOR, PROF. JAMES W., Union College, Schenectady, New York.
MAZIA, DR. DANIEL, Department of Zoology, Gowen Field, Boise, Idaho.
MEDES, DR. GRACE, Lankenau Research Institute, Philadelphia, Pennsylvania.
MEIGS, MRS. E. B., 1736 M Street, N.W., Washington, D. C.
MEMHARD, MR. A. R., Riverside, Connecticut.

MENKIN, DR. VALY, Duke University, School of Medicine, Durham, North Carolina.
METZ, PROF. CHARLES W., University of Pennsylvania, Philadelphia, Pennsylvania.
MICHAELIS, DR. LEONOR, Rockefeller Institute, 66th Street and York Avenue, New York City, New York.
MILLER, DR. J. A., Division of Anatomy, College of Medicine, University of Tennessee, Memphis, Tennessee.
MINNICH, PROF. D. E., Department of Zoology, University of Minnesota, Minneapolis, Minnesota.
MITCHELL, DR. PHILIP H., Brown University, Providence, Rhode Island.
MOORE, DR. CARL R., The University of Chicago, Chicago, Illinois.
MOORE, DR. J. A., Barnard College, New York City, New York.
MORGAN, DR. ISABEL M., Poliomyelitis Research Center, 1901 E. Madison Street, Baltimore 5, Maryland.
MORRILL, PROF. C. V., Cornell University Medical College, 1300 York Avenue, New York City, New York.
MULLER, PROF. H. J., Department of Zoology, Indiana University, Bloomington, Indiana.
NACHMANSOHN, DR. D., College of Physicians and Surgeons, 630 W. 168th Street, New York City, New York.
NAVEZ, DR. ALBERT E., Department of Biology, Milton Academy, Milton, Massachusetts.
NEWMAN, PROF. H. H., 173 Devon Drive, Clearwater, Florida.
NICHOLS, DR. M. LOUISE, Rosemont, Pennsylvania.
NONIDEZ, DR. JOSÉ F., Cornell University Medical College, 1300 York Avenue, New York City, New York.
NORTHROP, DR. JOHN H., The Rockefeller Institute, Princeton, New Jersey.
OCHOA, DR. SEVERO, New York University, College of Medicine, 477 First Avenue, New York 16, New York.
OPPENHEIMER, DR. JANE M., Department of Biology, Bryn Mawr College, Bryn Mawr, Pennsylvania.
OSBURN, PROF. R. C., Ohio State University, Columbus, Ohio.
OSTERHOUT, PROF. W. J. V., Rockefeller Institute, 66th Street and York Avenue, New York City, New York.
OSTERHOUT, MRS. MARIAN IRWIN, Rockefeller Institute, 66th Street and York Avenue, New York City, New York.
PACKARD, DR. CHARLES, Marine Biological Laboratory, Woods Hole, Massachusetts.
PAGE, DR. IRVINE H., Cleveland Clinic, Cleveland, Ohio.
PAPPENHEIMER, DR. A. M., 5 Acacia Street, Cambridge, Massachusetts.
PARKER, PROF. G. H., Harvard University, Cambridge, Massachusetts.
PARMENTER, DR. C. L., Department of Zoology, University of Pennsylvania, Philadelphia, Pennsylvania.
PARPART, DR. ARTHUR K., Princeton University, Princeton, New Jersey.
PATTEN, DR. BRADLEY M., University of Michigan Medical School, Ann Arbor, Michigan.
PAYNE, PROF. F., University of Indiana, Bloomington, Indiana.
PEEBLES, PROF. FLORENCE, Lewis and Clark College, Portland, Oregon.

PIERCE, DR. MADELENE E., Vassar College, Poughkeepsie, New York.
PINNEY, DR. MARY E., Milwaukee-Downer College, Milwaukee, Wisconsin.
PLOUGH, PROF. HAROLD H., Amherst College, Amherst, Massachusetts.
POLLISTER, DR. A. W., Columbia University, New York City, New York.
POND, DR. SAMUEL E., 53 Alexander Street, Manchester, Connecticut.
PRATT, DR. FREDERICK H., Wellesley Hills 82, Massachusetts.
PROSSER, DR. C. LADD, University of Chicago, Chicago, Illinois.
RAND, DR. HERBERT W., Harvard University, Cambridge, Massachusetts.
RANKIN, DR. JOHN S., Zoology Department, University of Connecticut, Storrs, Connecticut.
REDFIELD, DR. ALFRED C., Harvard University, Cambridge, Massachusetts.
REID, DR. W. M., Monmouth College, Monmouth, Illinois.
RENN, DR. CHARLES E., Harvard University, Cambridge, Massachusetts.
RENSHAW, DR. BIRDSEY, Rockefeller Institute for Medical Research, 66th Street and York Avenue, New York City, New York.
DERENYI, DR. GEORGE S., Department of Anatomy, University of Pennsylvania, Philadelphia, Pennsylvania.
REZNIKOFF, DR. PAUL, Cornell University Medical College, 1300 York Avenue, New York City, New York.
RICE, PROF. EDWARD L., Ohio Wesleyan University, Delaware, Ohio.
RICHARDS, PROF. A., University of Oklahoma, Norman, Oklahoma.
RICHARDS, DR. A. GLENN, Entomology Department, University Farm, Univ. of Minnesota, St. Paul 8, Minnesota.
RICHARDS, DR. O. W., Research Dept., American Optical Co., 19 Doat Street, Buffalo, New York.
RIGGS, LAWRASON, JR., 120 Broadway, New York City, New York.
ROGERS, PROF. CHARLES G., Oberlin College, Oberlin, Ohio.
ROGICK, DR. MARY D., College of New Rochelle, New Rochelle, New York.
ROMER, DR. ALFRED S., Harvard University, Cambridge, Massachusetts.
ROOT, DR. R. W., Department of Biology, College of the City of New York, Convent Avenue and 139th Street, New York City, New York.
ROOT, DR. W. S., College of Physicians and Surgeons, Department of Physiology, 630 West 168th Street, New York City, New York.
RUEBUSH, DR. T. K., Dayton, Virginia.
RUGH, DR. ROBERTS, Department of Biology, Washington Square College, New York University, New York City, New York.
SAMPSON, DR. MYRA M., Smith College, Northampton, Massachusetts.
SASLOW, DR. GEORGE, Washington University Medical School, St. Louis, Missouri.
SAUNDERS, LAWRENCE, W. B. Saunders Publishing Company, Philadelphia, Pennsylvania.
SAYLES, DR. LEONARD P., Department of Biology, College of the City of New York, 139th Street and Convent Avenue, New York City, New York.
SCHAEFFER, DR. ASA A., Biology Department, Temple University, Philadelphia, Pennsylvania.
SCHARRER, DR. ERNST A., Western Reserve University, School of Medicine, 2109 Adelbert Road, Cleveland 6, Ohio.
SCHECHTER, DR. VICTOR, College of the City of New York, 139th Street and Convent Avenue, New York City, New York.

SCHMIDT, DR. L. H., Christ Hospital, Cincinnati, Ohio.
SCHMITT, PROF. F. O., Department of Biology, Massachusetts Institute of Technology, Cambridge, Massachusetts.
SCHOTTÉ, DR. OSCAR E., Department of Biology, Amherst College, Amherst, Massachusetts.
SCHRADER, DR. FRANZ, Department of Zoology, Columbia University, New York City, New York.
SCHRADER, DR. SALLY HUGHES, Department of Zoology, Columbia University, New York City, New York.
SCHRAMM, PROF. J. R., University of Pennsylvania, Philadelphia, Pennsylvania.
SCOTT, DR. ALLAN C., Union College, Schenectady, New York.
SCOTT, PROF. WILLIAM B., 7 Cleveland Lane, Princeton, New Jersey.
SCOTT, SISTER FLORENCE MARIE, Professor of Biology, Seton Hill College, Greensburg, Pennsylvania.
SEMPLE, MRS. R. BOWLING, 140 Columbia Heights, Brooklyn, New York.
SEVERINGHAUS, DR. AURA E., Department of Anatomy, College of Physicians and Surgeons, 630 West 168th Street, New York City, New York.
SHANES, DR. ABRAHAM M., New York University, College of Dentistry, New York.
SHAPIRO, DR. HERBERT, Radiation Laboratory, Massachusetts Institute of Technology, Cambridge, Massachusetts.
SHELFORD, PROF. V. E., Vivarium, Wright and Healey Streets, Champaign, Illinois.
SHULL, PROF. A. FRANKLIN, University of Michigan, Ann Arbor, Michigan.
SHUMWAY, DR. WALDO, University of Illinois, Urbana, Illinois.
SICHEL, DR. FERDINAND J. M., University of Vermont, Burlington, Vermont.
SICHEL, MRS. F. J. M., 35 Henderson Terrace, Burlington, Vermont.
SINNOTT, DR. E. W., Osborn Botanical Laboratory, Yale University, New Haven, Connecticut.
SLIFER, DR. ELEANOR H., Department of Zoology, State University of Iowa, Iowa City, Iowa.
SMITH, DR. DIETRICH CONRAD, Department of Physiology, University of Maryland School of Medicine, Lombard and Greene Streets, Baltimore, Maryland.
SNYDER, PROF. L. H., Ohio State University, Department of Zoology, Columbus, Ohio.
SONNEBORN, DR. T. M., Department of Zoology, Indiana University, Bloomington, Indiana.
SPEIDEL, DR. CARL C., University of Virginia, University, Virginia.
STARK, DR. MARY B., 1 East 105th Street, New York City, New York.
STEINBACH, DR. H. BURR, Department of Zoology, Washington University, St. Louis, Missouri.
STERN, DR. CURT, Department of Zoology, University of Rochester, Rochester, New York.
STERN, DR. KURT G., Polytechnic Institute, Department of Chemistry, 85 Livingston Street, Brooklyn, New York.
STEWART, DR. DOROTHY R., University of Pennsylvania Medical School, Department of Physiology, Philadelphia 4, Pennsylvania.
STOKEY, DR. ALMA G., Department of Botany, Mount Holyoke College, South Hadley, Massachusetts.

STUNKARD, DR. HORACE W., New York University, University Heights, New York.
STURTEVANT, DR. ALFRED H., California Institute of Technology, Pasadena, California.
SUMMERS, DR. FRANCIS MARION, Univ. of California, College of Agriculture, Davis, California.
TAFT, DR. CHARLES H., JR., University of Texas Medical School, Galveston, Texas.
TASHIRO, DR. SHIRO, Medical College, University of Cincinnati, Cincinnati, Ohio.
TAYLOR, DR. C. V., Leland Stanford University, Leland Stanford, California.
TAYLOR, DR. WILLIAM R., University of Michigan, Ann Arbor, Michigan.
TEWINKEL, DR. L. E., Department of Zoology, Smith College, Northampton, Massachusetts.
TURNER, DR. ABBY H., Mt. Holyoke College, South Hadley, Massachusetts.
TURNER, PROF. C. L., Northwestern University, Evanston, Illinois.
TYLER, DR. ALBERT, California Institute of Technology, Pasadena, California.
UHLENHUTH, DR. EDUARD, University of Maryland, School of Medicine, Baltimore, Maryland.
VISSCHER, DR. J. PAUL, Western Reserve University, Cleveland, Ohio.
WAINIO, DR. W. W., New York University, College of Dentistry, New York City.
WALD, DR. GEORGE, Biological Laboratories, Harvard University, Cambridge, Massachusetts.
WARBASSE, DR. JAMES P., Woods Hole, Massachusetts.
WARD, PROF. HENRY B., 1201 W. Nevada, Urbana, Illinois.
WARREN, DR. HERBERT S., 1405 Greywall Lane, Overbrook Hills, Pennsylvania.
WATERMAN, DR. ALLYN J., Department of Biology, Williams College, Williamstown, Massachusetts.
WEISS, DR. PAUL A., Department of Zoology, The University of Chicago, Chicago, Illinois.
WENRICH, DR. D. H., University of Pennsylvania, Philadelphia, Pennsylvania.
WHEDON, DR. A. D., North Dakota Agricultural College, Fargo, North Dakota.
WHITAKER, DR. DOUGLAS M., P. O. Box 2514, Stanford University, California.
WHITE, DR. E. GRACE, Wilson College, Chambersburg, Pennsylvania.
WHITING, DR. PHINEAS W., Zoological Laboratory, University of Pennsylvania, Philadelphia, Pennsylvania.
WHITNEY, DR. DAVID D., University of Nebraska, Lincoln, Nebraska.
WICHTERMAN, DR. RALPH, Biology Department, Temple University, Philadelphia, Pennsylvania.
WIEMAN, PROF. H. L., University of Cincinnati, Cincinnati, Ohio.
WILLIER, DR. B. H., Department of Biology, Johns Hopkins University, Baltimore, Maryland.
WILSON, DR. J. W., Brown University, Providence, Rhode Island.
WITSCHI, PROF. EMIL, Department of Zoology, State University of Iowa, Iowa City, Iowa.
WOLF, DR. ERNST, Biological Laboratories, Harvard University, Cambridge, Massachusetts.
WOODRUFF, PROF. L. L., Yale University, New Haven, Connecticut.
WOODWARD, DR. ALVALYN E., Zoology Department, University of Michigan, Ann Arbor, Michigan.

WRINCH, DR. DOROTHY, Smith College, Northampton, Massachusetts.
YNTEMA, DR. C. L., Department of Anatomy, Cornell University Medical College, 1300 York Avenue, New York City, New York.
YOUNG, DR. B. P., Cornell University, Ithaca, New York.
YOUNG, DR. D. B., 7128 Hampden Lane, Bethesda, Maryland.

9. ASSOCIATES OF THE MARINE BIOLOGICAL LABORATORY

BARTOW, MRS. FRANCIS D.
BEHNKE, JOHN.
BROWN, MR. AND MRS. THEODORE.
CALKINS, MRS. GARY N.
COOPER, CHARLES P.
CROSSLEY, MR. AND MRS. ARCHIBALD.
CROWELL, PRINCE.
CURTIS, DR. WILLIAM D.
FAY, MRS. H. H.
FOSTER, RICHARD W.
GARFIELD, IRVIN McD.
GREEN, GEORGE S.
GREEN, MISS GLADYS.
HARRISON, R. G., JR.
HUNT, MRS. REID.
JANNEY, MRS. WALTER.
KNOWER, MRS. H. McE.
LILLIE, MRS. F. R.
McMITCHELL, MRS. J. McC.
MURPHY, DR. W. J.
NEWTON, MISS HELEN.
NIMS, MRS. E. D.
NORMAN, EDWARD A.
RIGGS, MRS. LAWRASON.
RUDD, MRS. H. W. D.
SAUNDERS, MRS. LAWRENCE.
STOCKARD, MRS. C. R.
SWOPE, MR. AND MRS. GERARD.
TEBBETS, WALTER.
WEBSTER, MR. AND MRS. E. S.
WICK, MRS. MYRON T.
WILSON, MRS. E. B.

THE INFLUENCE OF TEXTURE AND COMPOSITION OF SURFACE ON THE ATTACHMENT OF SEDENTARY MARINE ORGANISMS *

C. M. POMERAT AND C. M. WEISS

Medical Branch, University of Texas and the Woods Hole Oceanographic Institution *

Marine installations of various kinds necessitate exposure of construction materials under sea water. Data dealing with the amount of fouling accumulated by such materials are not abundant. Information which might be of aid to the scientist seeking the most favorable material upon which to collect sedentary organisms for study is also scanty. The present study was undertaken to determine the effect

TABLE I

Effect of surface texture of glass on attachment of sedentary organisms. (Numbers of individuals on each surface of 80 square inches of plate)

Surface number	Plain 0	Sand-blasted 1	Factrolite 2	Prestlite 3	Ribbed 4	Pentecor 5
Series No. 1, Tahiti Beach[1] 39 days (8/22/42–9/30/42)						
Hydroides sp.	143	265	152	506	349	197
Spirorbis sp.	85	188	122	90	163	110
Barnacles	1,948	1,072	1,162	975	1,674	2,140
Total	2,176	1,525	1,436	1,571	2,186	2,447
Average pop.	725.3	508.3	478.7	523.7	728.7	815.7
Average/square inch	9.1	6.4	6.0	6.5	9.1	10.2
Series No. 2, Miami Beach[2] 17 days (8/22/42–9/8/42)						
Wet weight (grams)	51.0	45.5	50.0	41.0	50.0	41.0
Dry weight (grams)	8.5	6.4	7.9	5.5	7.5	8.8
Barnacles	308	227	268	213	263	331
Series No. 3, Miami Beach[2] 30 days (9/15/42–10/15/42)						
Wet weight (grams)	164.5	174.0	149.0	150.0	126.0	155.5
Dry weight (grams)	51.5	50.0	30.0	24.0	24.0	33.0
Barnacles	642	515	554	778	798	977

[1] Subtropical testing service.

[2] Beach boat slips.

* The observations described here were made while the authors were engaged by the Woods Hole Oceanographic Institution in an investigation of fouling, under contract with the Bureau of Ships, Navy Department, which has given permission for their publication. The opinions presented here are those of the authors and do not necessarily reflect the official opinion of the Navy Department or the naval service at large. Contribution No. 349 from the Woods Hole Oceanographic Institution.

of surface irregularities and of substrate composition on the establishment of sessile populations. The experiments were conducted in Biscayne Bay at Miami, Florida, where subtropical conditions favor the attachment of fouling organisms throughout the year.

Grateful acknowledgment is made to Dr. A. C. Redfield and Dr. F. G. Walton Smith for many helpful suggestions.

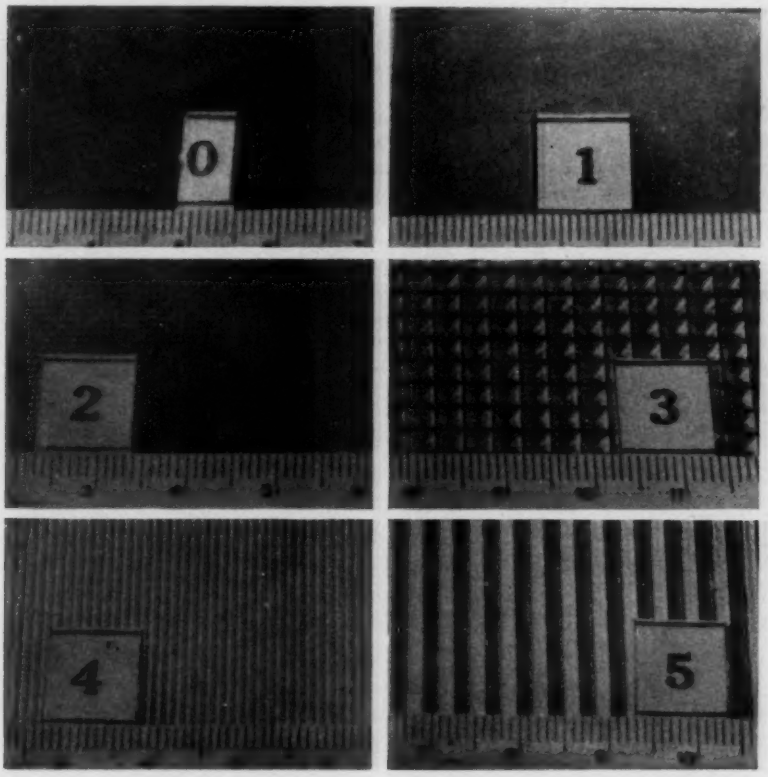


FIGURE 1. Glass surfaces used in testing the relation of surface irregularities to fouling. 0. Plain. 1. Sandblasted. 2. Factrolite. 3. Prestlite. 4. Ribbed. 5. Pentecor.

EFFECT OF SURFACE IRREGULARITY

Commercial glasses, manufactured by the Pittsburgh Glass Company, with various surface irregularities were used for this study. Six 8 × 10 inch glass plates were assembled, irregular surface down, in a rack suitable for floating on the surface of the water. The floats were constructed in such a way that sea water could move freely on both sides of the exposed surface. The backs of the panels which were all relatively smooth were placed upward. The fouling on the back surfaces was

not recorded. The surface irregularities of the panels are shown in Figure 1 and may be described as follows:

Surface Number:

0. *Plain*	Smooth glass, polished.
1. *Sandblasted*	Glass sandblasted on lower side.
2. *Factrolite*	Surface consisted of pyramidal depressions of which there were about 144 per square centimeter.
3. *Prestlite*	Approximately nine pyramidal depressions per square centimeter.
4. *Ribbed*	Surface of V-shaped grooves, nine grooves per centimeter of width.
5. *Pentecor*	Approximately three V-shaped grooves per centimeter of width.

Results obtained from three series of experiments in which the glass surfaces were exposed are shown in Table I.

The Sessile populations which grew on the glass plates were composed primarily of barnacles and tubeworms, with irregular, perhaps seasonal, appearances of tunicates and *Anomia* sp. Barnacles (*B. improvisus* and *B. amphitrite niveus* in order of relative abundance) were numerous in both locations, but those at Tahiti Beach were always very small compared to those at Miami Beach. Many more barnacles attached to the lower (shaded) surfaces of the panels than to the upper surfaces where light was more abundant. This is in agreement with the experience of Pomerat and Reiner (1942), who report that larger numbers of barnacles accumulate on dark surfaces than on light surfaces. The shaded undersides of the glass panels, being darker than the upper sides, appear to attract more cyprids and hence show a greater barnacle accumulation.

The various surface textures of glass had little influence on the number of attached organisms. In these experiments barnacles were consistently slightly more numerous on Pentecor than on smooth glass. This behavior was confirmed in the experiment reported in the following section although conditions of exposure were not exactly parallel. In the first experiment the glass panels were floated at the surface in a shaded location, while in the second they hung vertically below low tide

TABLE II

Influence of substrate on fouling, sixty days' exposure at the beach boat slips, September 25, 1942–November 25, 1942

Substrate	Weight of fouling on panel area of 264 sq. in., that of wood panels employed	
	Wet weight grams	Dry wt. grams
1. Dade County pine	675.1	346.5
2. Gum	1127.6	531.4
3. Magnolia	1165.4	446.4
4. White pine	968.7	446.8
5. Cypress	954.8	392.0
6. Tile	980.1*	487.3
7. Cement	1033.0*	534.1
8. Glass	386.1	167.3

* Corrected to an area, 264 sq. in., equal to that of the wood panels.

under sun exposure. Counts of tubeworms were made on only one set of exposures. *Hydroides* sp. was most abundant on Prestlite and *Spirorbis* sp. was most abundant on sandblasted glass.

Composition of the Surface

Unpainted panels of wood of five species, clay roofing tiles, cement roofing plates, and a glass panel were exposed for 60 days at the Beach Boat Slips in Miami Beach.

Table III

Effect of substrate on fouling, exposures of three months at South Dock, Belle Isle, Miami Beach, Florida, January 9, 1943–April 9, 1943, all materials applied to, or mounted on, wood unless otherwise noted

Composition of surfaces	Wet weight* (grams)	Dry weight* (grams)	Number* of barnacles	Notes
Plastics				
1. Celluloid	3.8	2.2	11	Thin coat of algae.
2. Plasticel	24.3	12.2	124	Barnacles' bases easily removed.
3. Lucite	5.6	1.7	41	
4. Formica	6.9	3.2	11	
5. Isobutyl Methacrylate	15.4	7.2	70	Film applied to glass panel. Plastic peels intact with barnacles.
Glass				
6. Prestlite	57.0	25.2	176	Some barnacles 12 mm. across.
7. Pentecor	46.0	25.0	148	Some barnacles 12 mm. across.
8. Sandblasted	23.6	7.0	46	6 calcareous tubeworms; tunicates.
9. Smooth	4.5	1.7	16	Green slime may have caused fish to remove young barnacles.
*Paints and ingredients** Coatings applied to steel panels*				
10. Ester gum vehicle	36.3	8.1	58	Tunicates and bryozoa.
11. Rosin vehicle	2.7	0.4	0	Fish spawn both sides.
12. Anticorrosive paint 42-A	2.7	0.5	9	Baracles very small.
13. Vehicle of 15RC	6.1	3.3	43	
14. Antifouling paint 7C	0.0	0.0	0	Some slime film.
15. Antifouling paint 8C	0.6	0.3	14	Small barnacles close to edge.
Coatings Applied to Wood				
16. Ceraloid	57.6	38.5	183	
17. Paraffin	11.3	6.1	59	Lomnoria active in breaking paraffin.
18. Asphaltum	121.4	34.3	768	Barnacles only.
19. Asphaltum varnish	67.8	13.8	256	Some bryozoa.
20. Spar varnish	45.1	7.0	304	
21. Navy grey	41.6	5.6	150	Algae.
22. Anti-corrosive 42-A	48.2	10.7	156	

* Corrected to an area of 144 square inches.

** Anticorrosive 42A is a standard Navy formula. Vehicle of 15RC is the non-pigmented portion of a standard Navy antifouling paint. Antifouling paints 7C and 8C are experimental modifications of a standard Navy antifouling paint of the cold plastic type in which the toxic pigment is reduced to 50 and 60 percent of the normal value.

TABLE III—*Continued*

Composition of surfaces	Wet weight* (grams)	Dry weight* (grams)	Number* of barnacles	Notes
Woods				
23. Dade County pine (soaked 60 days)	395.2	120.7	748	Bryozoa.
24. Gum (soaked 60 days)	452.1	133.4	686	
25. Dade County pine (unsoaked)	144.3	27.3	125	Hydrozoa, bryozoa.
26. Gum (unsoaked)	249.8	43.5	222	
27. Soft pine	57.6	11.5	184	
28. Teak	143.8	88.7	306	Large barnacles.
29. Maderia	173.7	84.2	358	Many fish eggs.
30. Greenheart	77.0	40.8	342	
31. Balsa	2.9	1.6	5	Wood very soft.
Metals				
32. Steel	224.4	42.8	88	
33. Galvanized iron	2.6	0.7	6	Barnacles easily removed.
34. Zinc	1.0	0.2	0	Active corrosion.
35. Lead	30.6	50.9	396	Large barnacles.
36. Monel	1.6	0.5	6	Many fish eggs.
37. Nickel	43.2	10.7	126	
38. Galvanized iron pipe	4.7	3.0	27	Barnacle on rusted threads and damaged edges.
Miscellaneous				
39. Linoleum	79.7	23.0	193	
40. Deck canvas no. 10	5.1	2.3	7	Sagging-algae eaten by fish.
41. Sole leather	32.4	12.4	66	
42. Masonite, heat tempered	138.6	31.8	594	Brown tunicates.
43. Asbestos	284.2	65.9	980	Bryozoa, *Anomia*, hydrozoa, calcareous tubeworm.

All panels were suspended in a vertical position approximately two feet beneath the mean low water mark. The site was well shaded by a protecting roof. The results obtained are presented in Table II.

The weights of the populations (barnacles, tubeworms, tunicates, bryozoa, and algae) which accumulated on the woods, tile, and cement were of the same order of magnitude, though variations as great as 59 per cent were observed. The weight of organisms accumulated on glass was approximately 30 per cent of that collected from other substrate materials.

A much larger number of materials were tested in a second experiment, the results of which are given in Table III. Exposure was made for three months at South Dock, Belle Isle, in Miami Beach, where conditions of bright sunlight, active current movement, and moderate fouling incidence were found. Growth on the panels consisted primarily of barnacles (*B. improvisus* and *B. amphitrite niveus*) with occasional tufts of hydrozoa and patches of colonial tunicates. A blanket of algae having very short filaments grew on panels of light color or shaded background. Large sets of fish eggs were found on the rosin vehicle and Monel. Borings of *Limnoria* sp. were everywhere evident in unprotected wood.

The substrates accumulating heaviest populations were asbestos, asphaltum, Dade County pine (pre-soaked 60 days), gum wood (pre-soaked 60 days) and Masonite. Asbestos shingle, commonly used as clapboarding, yielded the richest harvest as measured by the number of barnacles. A comparison of asbestos and Masonite, two of the best collectors, is shown in Figure 2. The asphaltum used was of the type employed as aquarium cement. It accumulated barnacles only.

Panels of gum and Dade County pine, which had been exposed for 60 days in the earlier test reported in Table II, were included for comparison with unsoaked specimens of these woods. The unsoaked woods developed much less fouling.

FIGURE 2. Accumulation of fouling organisms on masonite and asbestos after 90 days' exposure at Belle Isle, Miami Beach, Florida.

Intact galvanizing on iron was very resistant to marine life. No barnacles were obtained on zinc, on the experimental antifouling paint 7C or on rosin vehicle, a common paint component.

Materials with hard non-porous and non-fibrous surfaces were in general rather poor collectors of fouling. The best accumulation of sedentary populations was found on surfaces which were porous and/or fibrous. Surface of paints, paint ingredients and linoleum are in general non-porous and non-fibrous. Compared to the size and strength of the barnacle cyprid they are also smooth and hard. The histogram (Fig. 3) summarizes the collective efficiency of the substrates.

Some results were undoubtedly spurious, and these should be noted. Fouling on the antifouling paint 8C which occurred along the edges of the panel was probably

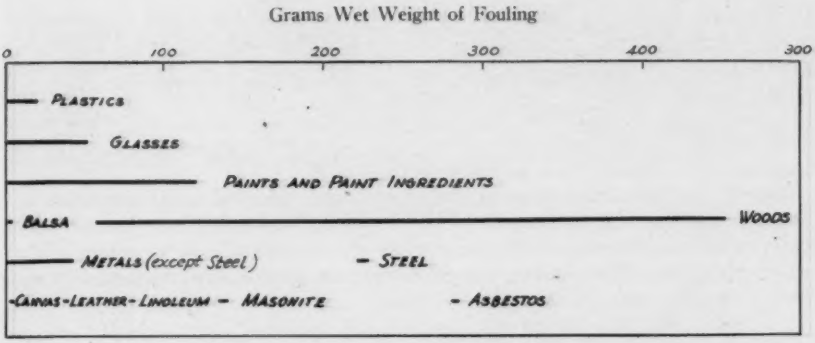


FIGURE 3. Relative amounts of fouling on various classes of materials used as test panels.

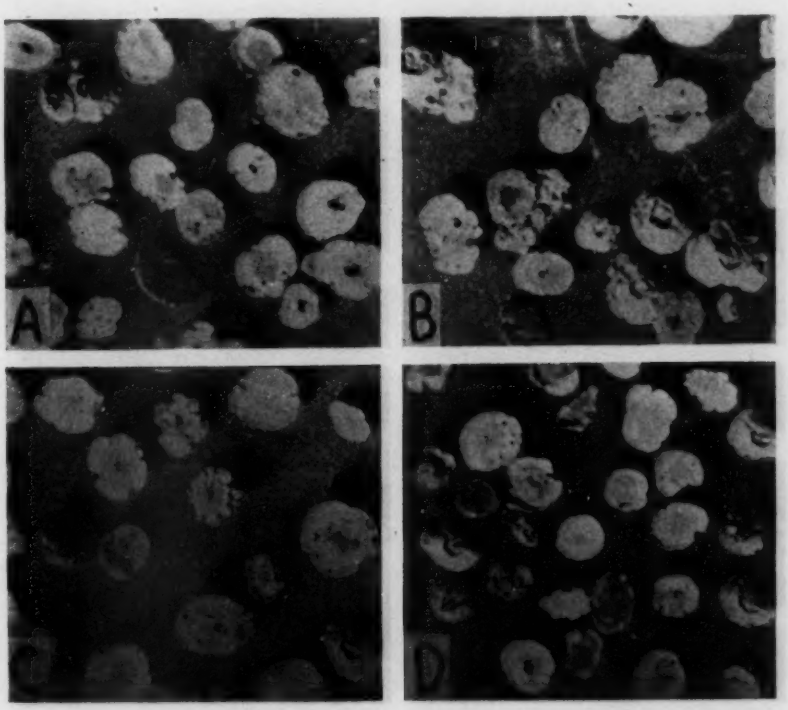


FIGURE 4. Bases of barnacles grown on various substrates. A. Navy grey. B. Antifouling paint 15RC. C. Ester gum. D. Anticorrosive paint 42A.

due to imperfections of the paint surface. In contrast, 7C which contained less copper was not fouled. Deck canvas and smooth glass both supported a culture of green algae which evidently served as food for fish. Active feeding on these panels unquestionably disturbed other fouling organisms. Balsa wood was apparently sloughing its surface and thus loosening attached forms. In spite of these minor qualifications, the results involve a range of population numbers sufficiently wide to indicate the relative merits of the substrates used.

One of the most interesting of the results was observed when barnacles were removed from the various substrates. Some of the substrates bore barnacles with deeply scalloped margins (Fig. 4) instead of the typical smooth edges. These margins suggested that localized irregular marginal growth interruptions had taken place. Such barnacles were collected from:

Spar varnish
Linoleum
Navy grey topside paint (P–50)
Antifouling paint vehicle 15RC
Ester gum paint vehicle
Anticorrosive paint 42–A

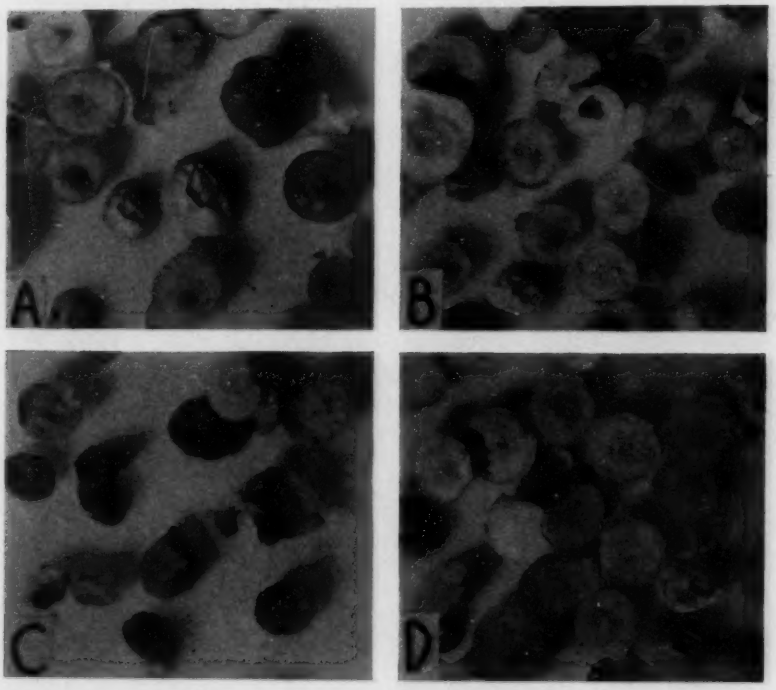


FIGURE 5. Bases of barnacles grown on various substrates. A. Isobutyl methacrylate. B. Plasticel. C. Soft paraffin. D. Ceraloid.

Barnacles growing on soft paraffin had distinctly concave bases. Mosaics of bases with angular margins were typical of barnacles attached to lead but were also found on other overcrowded substrates. It was possible to remove barnacles with intact bases very easily from several materials, including plasticel, ceraloid, and isobutyl methacrylate (Fig. 5). This finding might prove useful in designing experiments in which the minute anatomy of basal structures was to be studied.

Summary

1. Submerged samples of 40 different construction materials were used as substrates for the collection of sedentary populations. The barnacle counts in the populations ranged from 980 on asbestos shingles to zero on zinc and on two paint coatings, after three months' immersion in Biscayne Bay at Miami Beach, Florida.

2. Various surface textures of glass plates were found to exert no significant influence on the accumulation and growth of sedentary marine organisms, although smooth clear glass accumulated smaller populations in the comparatively short exposure periods, 1–3 months .

3. The results suggest that efficiency of a substrate as a fouling collector is in general correlated with porosity of surface or with fibrous nature of surface. Smooth, non-porous, non-fibrous surfaces, especially if also hard, seem to be poor accumulators of sedentary organisms.

4. Further testing of substrates is greatly to be desired in this connection.

References

Pomerat, C. M., and E. R. Reiner, 1942. The influence of surface angle and of light on the attachment of barnacles and other sedentary organisms. *Biol Bull.*, **82** (1) : 14.

THE DEVELOPMENTAL HISTORY OF AMAROECIUM CONSTELLATUM. II. ORGANOGENESIS OF THE LARVAL ACTION SYSTEM

SISTER FLORENCE MARIE SCOTT

The Marine Biological Laboratory, Woods Hole, Mass., and the Biology Department, Seton Hill College, Greensburg, Pennsylvania

Introduction

The early development of the embryo of *Amaroecium constellatum* has been presented in a previous paper (Scott, 1945). The accumulation of yolk modifies the pattern of mosaic development characteristic of Tunicates to the extent that gastrulation is accomplished in an atypical manner. Convergence of the cells of the lateral margins of the posterior blastoporal lip is accomplished to the left of the mid-line. The neural plate elongates posteriorly at the place where the lateral blastoporal lips meet and close. The chordal cells are inflected at the anterior lip and lie in the median axis. The potential muscle cells of the morphological right side lie dorsal to the notochord as a result of their growth across the mid-dorsal plane, the muscle cells of the morphological left side lie below the level of the notochord on the curved left side of the embryo. The two groups of muscle cells are separated by the posterior extension of the neural plate.

Materials and Methods

Amaroecium constellatum is abundant along the eastern coast of the United States. The breeding season lasts throughout the summer months. Material for this study was collected at Woods Hole, Massachusetts. The embryos, squeezed from adult colonies, were selected and arranged into a progressive series of stages for study. They were fixed in Bouin's fluid. Some were stained by Conklin's modification of Delafield's haematoxylin, others with borax-carmine, then cleared according to the benzyl-benzoate method described in Romeis' "Taschenbuch der Mikroscopischen Technik." Corresponding stages were sectioned serially, stained in Mayer's or Gallagher's or iron haematoxylin, and counterstained with eosin or triosin. All drawings were made with the aid of a camera lucida. The photomicrographs were made with a Leitz "Macca" camera using Zeiss apochromat, 20 ×, and fluorite oil immersion, 100 ×, objectives with a Zeiss microscope.

Later embryonic development

It seems advisable to present a descriptive series of developmental stages that may be used as points of reference for structures differentiating during the organ-forming period. For convenience the developmental period following gastrulation is divided into four stages; 1) the tail bud stage, 2) early tadpole stage, 3) pre-hatching stage, and 4) the free-swimming tadpole stage. The free-swimming larva

or tadpole has been described thoroughly by Grave (1921) and shall be presented here in brief summary since reference to it is necessary. A short description of the external appearance of these stages will be given first and referred to in subsequent treatment of organogenesis as Stages I, II, III, and IV. The terms, larval action system and adult action system, used by Grave (1935, 1944) will be adopted for the structures functioning during larval life and those functioning during adult life respectively.

The tail bud stage

By the end of gastrulation the embryo is approximately spherical except for a shallow postero-ventral invagination of the ectoderm constricting tail from trunk region. The furrow appearing first on the right side is deeper there, and less deep as it extends to the left side. The tail bud is short and rounded, curving immediately toward the ventral side of the trunk. Through the thin epidermis quadruple rows of large muscle cells can be seen lying dorsal and ventral to the notochord. The neural plate is elevated at the periphery to form the neural groove, enclosing anteriorly a wide depression, the presumptive brain region, posteriorly a narrow, trough-like depression lying to the left of the notochord, the presumptive neural tube (Fig. 1*A*).

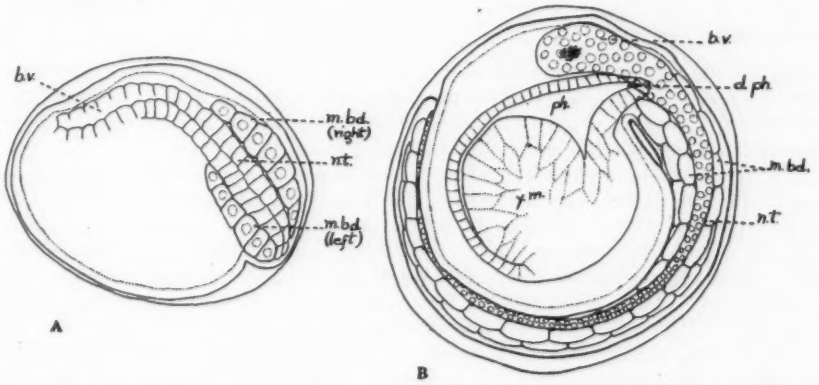


FIGURE 1. *A*. Stage I, embryo before neural folds close. 160×. *B*. Stage II, early tadpole; beginning of differentiation of digestive and nervous systems. 160×. *b. v.*, brain vesicle; *d. ph.*, dorsal diverticulum of pharynx; *m. bd.*, muscle band; *n. t.*, neural tube; *ph.*, pharynx; *y. m.*, yolk mass.

A transverse section through the tail bud stage discloses that the embryo is solid. A single layer of definitive endoderm lies under the concave neural plate (Fig. 5*E*). This layer of cells develops from the cells that form the superficial "pseudo-invagination" cavity of gastrulation. The depression closes by a reversal in change of shape of the cells involved rather than by approximation of the lips of the blastopore thus producing a solid archenteron (Scott, 1945). The endodermal cells spread under and anterior to the neural plate. Ventral to them is located the mass of heavily yolk-laden cells derived from the macromeres. Wedged between the

thin ectoderm and the solid endoderm on either side is a mass of mesenchyme, small, polygonal cells with prominent nuclei (Fig. 5*E*).

Posteriorly the definitive endoderm lies adjacent to the chordal cells which are beginning to interdigitate in the base of the tail bud. The mesenchyme terminates abruptly in this region against the muscle cells of the tail.

Early tadpole stage

The embryo increases in size and acquires the shape that justifies its being called "tadpole." The trunk region elongates slightly in the antero-posterior axis remaining curved at the anterior end. The tail encircles the body meridionally as it grows in length. The embryo is still opaque.

The neural folds are closed, the position of the sensory vesicle being marked by aggregations of black pigment which show through the surface of the body. The neural tube is faintly visible along the side of the tail. More conspicuous are the large muscle cells dorsal and ventral to the prominent notochord which forms the axis of the tail throughout its length. Dorsally, on either side of the sensory vesicle there is a slight ectodermal invagination, rudiments of the atrial chambers. The embryo is confined within a test the cells of which are arranged in a compact layer (Fig. 1*B*).

Pre-hatching stage

Changes in the external appearance of the later embryo depend on the development of siphons and adhesive papillae and the secretion of a tunic. As body growth continues and organs of the larval action system differentiate, the body becomes transparent except where the mass of yolk is lodged in the pharynx.

The trunk region continues to elongate antero-posteriorly becoming elliptical in shape. Posteriorly the body narrows to the base of the tail; anteriorly it flares in the dorso-ventral axis in relation to the vertical position of the adhesive papillae. Laterally the body is compressed. A thickening layer of tunic invests the entire trunk. It is indented at the junction of trunk and tail and continues over the surface of the tail. The tail encircles the body meridionally being pressed into a groove in the tunic. The tunic of the tail projects laterally into fins.

The sensory vesicle occupies a dorsal position at the posterior end of the trunk. Two masses of pigment project into its cavity. Immediately in front of it lies the elevation of the oral siphon; behind it and on the posterior curve of the body lies the atrial siphon. Much of the internal structure is visible through the tunic and mantle. The incipient adhesive papillae appear as three disc-like projections in verticle series at the rounded anterior end (Fig. 2).

The free-swimming tadpole stage

The trunk of the tadpole of Amaroecium at its release measures about 600 micra in length; it measures about 270 micra in depth. The tubular atria with their triple rows of gill slits are pressed into the dorsal pharynx through half of its length posteriorly. An obvious structure in the pharynx is the dorsal, heavily ridged endostyle which seems to rest on the lateral masses of yolk that form the wall of the pharynx. The transparent pericardium occupies a large space below the yolk ante-

riorly in front of the loop of alimentary tract. On the right side of the body the stomach extends along the posterior and ventral curvature of the yolk. On the left the narrow intestine curves along the side of the stomach up to the left atrium where it terminates. The root of the tail lies in the posterior third of the length of the body.

Anteriorly, the adhesive papillae project into the tunic in a vertical row slightly to the right of the median plane. The test vesicles lie loosely within the tunic or many of them, even at the time of hatching, retain a slender connection with the cone or ridge from which they originate. Where the tail is continuous with the trunk the tunic dips down into an abrupt pocket. The epidermis secretes a thin sheath of tunic about the tail. Laterally it expands into wide sail-like fins (Fig. 3).

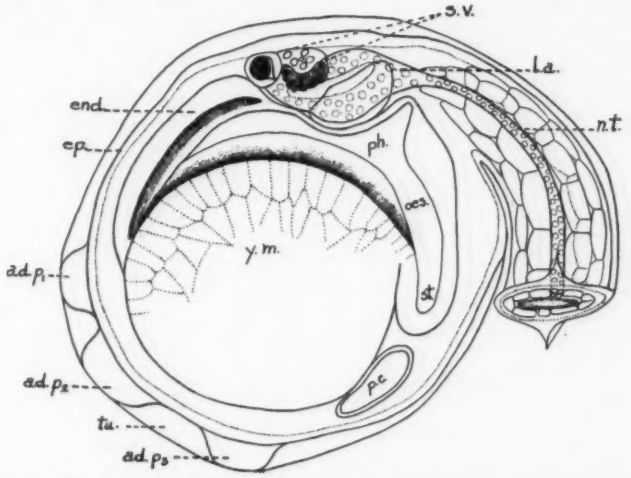


FIGURE 2. Stage III, lateral view of tadpole with incipient adhesive papillae. About 120 ×. *ad. p.*, adhesive papillae; *end.*, endostyle; *ep.*, epidermis; *l. a.*, left atrium; *n. t.*, neural tube; *oes.*, oesophagus; *p. c.*, pericardial cavity; *ph.*, pharynx; *st.*, stomach-intestine rudiment; *s. v.*, sensory vesicle; *tu.*, tunic; *y. m.*, yolk mass.

ORGANOGENESIS OF THE LARVAL ACTION SYSTEM

Digestive system

The pharyngeal cavity develops in Stage II by delamination between the layer of definitive endoderm and the mass of yolk-laden cells, appearing first below the brain and spreading from that point (Fig. 1*B*, 5*F*, 6*E*). It extends back to the base of the notochord as an upwardly directed diverticulum. Ventral to the base of this projection a second invagination appears, the rudiment of the stomach and intestine located a little to the right of the median plane on the inner side of the visceral ganglion (Fig. 2, 6*F*).

The pharynx deepens in Stage III encroaching upon the mass of yolk cells. Gradually thin septa of epithelium divide the yolk mass into four compact longitudinal columns, the two on each side being continuous at the bottom. The central

two are lower than the outer two, thus providing greater depth for the limited pharyngeal cavity (Fig. 6*A*, *F*). This supply of nutritive material in the pharynx remains to be digested during the active life of the larva and throughout the critical period of metamorphosis. All other tissues lose their meager supply of yolk almost entirely, leaving their cytoplasm clear.

Along the roof of the pharynx, anterior to the place of origin of the oral siphon, the epithelium rises up into a double fold enclosing the endostyle, restricted to the dorsal side above and between the lateral masses of yolk and passing to the anterior end of the yolk mass (Fig. 2, 6*A*). Before the tadpole is released from its test, the cells in the floor of the groove develop long cilia. The pharynx grows out above and below the atrial sacs, bringing the mesial atrial and lateral pharyngeal walls into intimate contact (Fig. 6*B*).

Due to the combined activity of atrial and pharyngeal epithelia, three horizontal rows of gill slits are formed, each consisting of seven or eight perforations. The

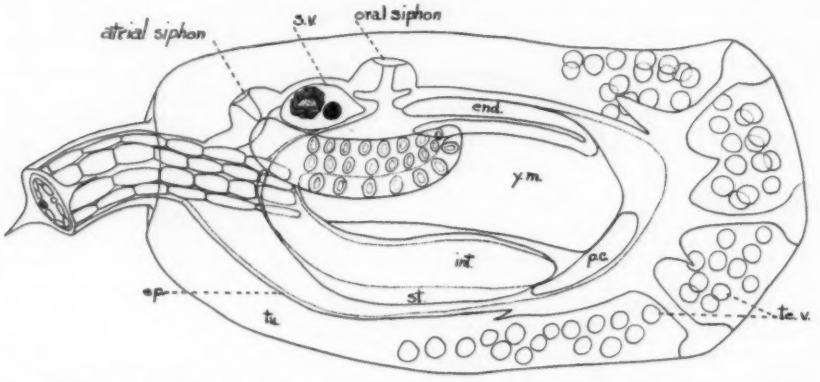


FIGURE 3. Stage IV, tadpole at hatching. About 120 ×. *end.*, endostyle; *ep.*, epidermis; *int.*, intestine; *p. c.*, pericardial cavity; *st.*, stomach; *s. v.*, sensory vesicle; *te. v.*, test vesicles; *tu.*, tunic; *y. m.*, yolk mass.

bordering cells of each gill develop a heavy brush of cilia, precocious equipment from the functional point of view. Even though the mouth breaks through to the branchial chamber, the tunic fills up the oral and atrial siphons until metamorphosis is completed.

The rudiment of the oesophagus grows forward along the curvature of the yolk and dilates to form the stomach. The diverticulum extends to the midventral region of yolk where it turns sharply upon itself and continues backward as the slender intestine. With a gradual slope upward the intestine retraces the course of the stomach on its left side terminating ventral to the posterior end of the left atrium (Fig. 3, 6*B*). Later the anus opens into the atrium here.

There are no cilia evident in the intestine or stomach during this period of development. The wall of the stomach is thicker than the wall of the remaining parts of the digestive tract although the alimentary epithelium, throughout its length, consists of a single layer of cells.

With rapid general growth of the body, the loop of intestine and stomach increases in length anteriorly, extending through the posterior half of the body cavity below and behind the yolk-laden pharynx (Fig. 3). The pericardium lies directly in front of it. Between the arms of the loop posteriorly are lodged the bases of the axial organs of the tail.

Atrium—During Stage II the atrium or peribranchial sac appears as a pair of ectodermal invaginations, one on either side of the sensory vesicle (Fig. 6*E*). At the place of its origin the neck of each depression constricts and separates from the surface.

In the transition from Stage II to Stage III, the atria, in contact with the lateral endodermal wall of the pharynx, grow in an anterior direction only, with the result that the atrial chambers are horizontal capsular cavities located dorsally, one on either side of the pharynx (Fig. 6B). They extend through the posterior two-thirds of the trunk, curving gently upward posteriorly where they grow towards each other and unite behind the pharynx (Fig. 3). The atrial siphon opens through the dorsal wall of this connecting canal between the two cavities.

The atrial walls are characteristically thin and the cells lose their intercell membranes. Occasional yolk granules are scattered through the cytoplasm. During Stage III the gill slits perforate the walls in three horizontal rows on the inner side in direct contact with the wall of the pharynx. The lowermost row develops first, the atrial and pharyngeal fusing first in these regions. The slits number between seven and nine in each row. Later in the free-swimming period the cells bordering the gill aperture produce long cilia. The endoderm has no part in atrial formation except insofar as the gill slits are the product of joint activity of atrial and pharyngeal walls (Caullery, 1895).

Oral and Atrial Siphons—Late in Stage III the dorsal ectoderm in front of the sensory vesicle thickens and invaginates, pushing the endoderm of the pharynx before it. The circle of epidermis around the invaginated area becomes elevated, giving the oral siphon a crater-like appearance (Fig. 6*B*). The floor of the invagination thins out in a flat layer against the pharyngeal roof with which it is in contact. The lower part of the cavity projects outward from the center and produces a ring-shaped extension on the mouth opening. The oral cavity assumes the shape of a flask with a long neck and a flattened base (Fig. 3). Into this ectodermal cavity, or stomodaeum, the hypophysial duct opens, just before hatching of the tadpole. Although the oral plate breaks through late in the tadpole's development, the tunic fills up the stomodaeal portion and prevents the passage of both food and water during larval life.

The atrial siphon, like the oral, is formed by ectodermal invagination. The thickened mantle is elevated, raising the siphon above the level of the rest of the mantle in knob-like fashion (Fig. 6*C*). The floor of the invagination fuses with the dorsal wall of the connecting arm of the atrium. The atrial siphon is situated on the downward curve of the dorsal surface just posterior to the sensory vesicle and anterior to the insertion of the tail (Fig. 3, 6*G, H*). The epithelial lining of the oral and atrial siphons projects into each opening at several points forming small tentacles. The mesenchymatous muscles in the mantle in this region provide the contractile elements that control the apertures when the siphons begin to function.

Heart and pericardium

Towards the end of Stage III, the endodermal cells extend completely around the yolk mass as a definite epithelium. Mid-ventrally it evaginates into the body space and constricts off from the yolk epithelium. The bladder-like vesicle is the pericardium which invaginates mid-dorsally into an inner enclosed vesicle, the heart. The cells lose their inter-cell membranes and the nuclei bulge irregularly in both cardial and pericardial walls (Fig. 6*A*). The heart does not develop beyond this point at present, the circulatory system not functioning during larval life.

The nervous system

The neural folds of Stage I close in the early phase of Stage II thus forming the hollow nervous system typical of chordates except in one point, the curving of the neural tube through 90° to the left of the brain region. The anterior portion of the nervous system produces the sensory vesicle with its sensory organs, the hypophysis, definitive ganglion, and the so-called subneural gland. The intermediate part including the origin of curvature and a small contribution from the brain region gives rise to the visceral ganglion and the spinal enlargement, the posterior part becomes the neural tube.

The cavity of the brain region is slightly dilated and its wall uniformly thick. The neural tube consists, in section, of four cuboidal cells surrounding a small lumen (Fig. 4*C*). Cell membranes in both regions are distinct at this stage, the nuclei are large and contain heavily staining nucleoli. The cytoplasm is reticular in appearance and has occasional yolk granules.

During Stage III the brain vesicle differentiates into two structures, the sensory vesicle in the entire right side and the rudiment of the hypophysis on the left posterior side (Fig. 4*A*, 5*A*). The vesicle expands, its walls becoming thin; the rudiment of the hypophysis remains small with thick walls. This secondary cavity is separated completely from the sensory vesicle at the region of evagination but their walls remain attached throughout subsequent development (Fig. 5*B*, *C*).

The sensory vesicle—Two sensory structures develop in the sensory vesicle, the statolith and the eye. The left posterior wall of the vesicle thickens, the right wall expands dorsally and laterally; all the cells lose their inter-cell membranes. The left wall of the cavity remains thick and constitutes the sensory ganglion of the brain. One cell on the ventro-anterior wall projects into the cavity and large pigment granules are deposited in its cytoplasm; these coalesce to form the statolith (Fig. 4*B*, 5*B*). In Stage IV the statolith is a spherical mass of pigment confined within the cell membrane and attached to the ganglionic wall by a stout stalk, the remaining part of the cell (Fig. 4*D*, 5*C*, *D*).

A group of cells situated dorso-laterally at the left posterior limit of the vesicle initiates the development of the eye by the deposition of pigment granules of much smaller size than those that form the statolith. Absence of cell membranes makes it difficult to ascertain the number of cells that participate in this activity. The pigment is deposited in the shape of a cup, its concavity facing dorso-laterally and to the right within the vesicle. Three ganglionic cells which retain their membranes fill up the concavity in series. They secrete globules of liquid which increase in size both by the gradual addition of the secretion and by the fusion of globules. The globules of liquid form the so-called lens cell (Fig. 4*A*, *B*, *D*, 5*D*). The nuclei

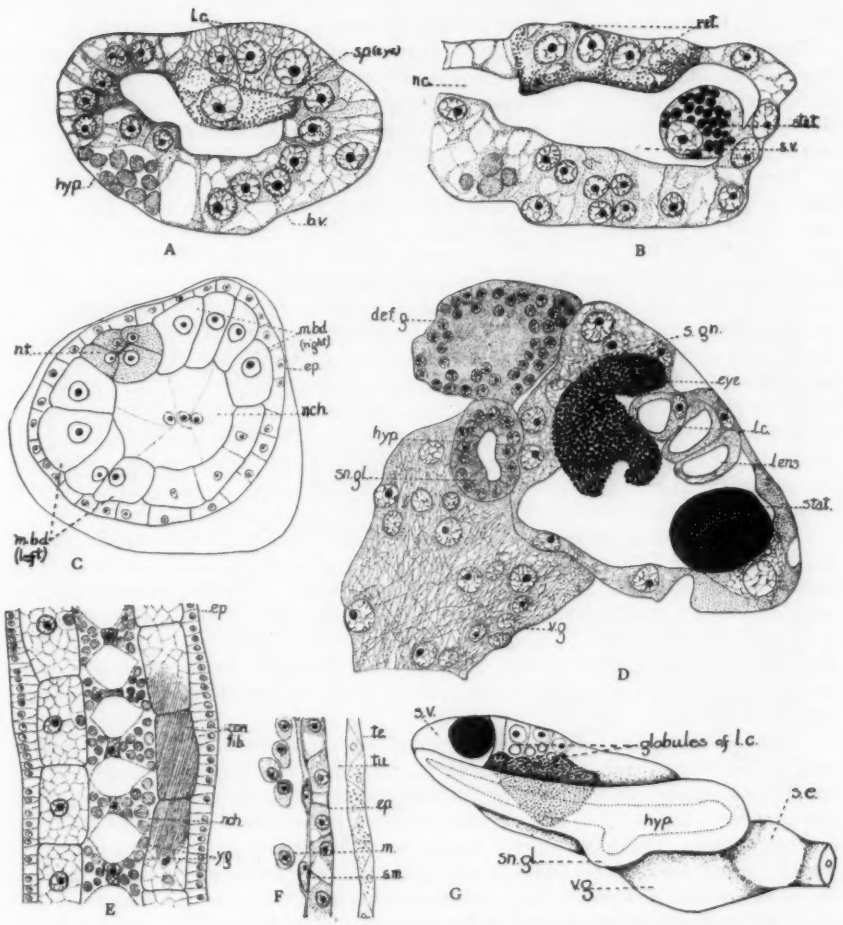


FIGURE 4. *A*. Transverse section through brain after the neural folds close, Stage II. 750 ×. *B*. Longitudinal section through brain of same stage. 750 ×. *C*. Cross section through tail of tadpole, Stage III. 300 ×. *D*. Section through brain of tadpole just before hatching, oblique to include both sensory organs. 750 ×. *E*. Longitudinal section through tail of tadpole in Stage III. 300 ×. *F*. Section through epidermis and test of Stage III. 750 ×. *G*. Reconstruction of brain and related structures of Stage III, viewed from left side. 300 ×. *b. v.*, brain vesicle; *con. fib.*, contractile fibrils; *def. g.*, definitive ganglion; *ep.*, epidermis; *hyp.*, hypophysis; *l. c.*, lens cell; *m. bd.*, muscle band; *n. c.*, neural canal; *nch.*, notochord; *n. t.*, neural tube; *ret.*, retinal cells of eye; *s. gn.*, sensory ganglion; *sn. gl.*, subneural gland; *stat.*, statolith; *s. c.*, sensory cell; *s. e.*, spinal enlargement; *s. m.*, smooth muscle cells of mantle; *s. p.*, sensory pigment; *t. c.*, test cells; *tu.*, tunic; *v. g.*, visceral ganglion; *y. g.*, yolk granules.

which at first occupy a central position in the cells are pushed to the periphery as the lenses, increasing in size, come eventually to monopolize the entire cell.

The pigment granules of the eye always remain discrete, not coalescing as do those of the otolith. Extending through the concentrated pigment are small rods of clear cytoplasm. They run from the base of the cup back towards the ganglion. Seven or eight of them may be seen in embryos of Stage IV that are mounted in a mixture of benzyl-benzoate and oil of wintergreen.

The hypophysis—The rudiment of the hypophysis early in Stage III appears as an extension or small evagination of the brain cavity (Fig. 4*A*, 5*A*). The cells retain their membranes, their nuclei are smaller than those of the adjoining part of the brain. Histologically they present the appearance of epithelial tissue. Upon its separation from the primary cavity during Stage III it elongates anteroposteriorly along the left side of the sensory ganglion (Fig. 4*G*). In Stage IV it ends blindly at the posterior wall of the oral siphon. Later these walls fuse and the hypophysis communicates with the posterior region of the stomodaeum, extending along the side of the ganglion with a gentle slope upward as far as the atrial siphon where it terminates blindly. The floor of the duct, corresponding in position to the region of the eye, deepens abruptly (Fig. 4*D*, *G*). The ventral wall of the pocket becomes slightly thicker, the indentation with its thickened floor constituting the subneural gland. Hjort (1896) reviews the opposing views concerning this structure in the early works on Tunicates.

The definitive ganglion—By a proliferation of cells in the mid-region of its roof in Stage II the hypophysial duct produces an oval mass containing small nuclei similar to those in the hypophysial duct itself. The cell membranes disappear and the nuclei wander out toward the periphery where they collect in several rows with the granular cytoplasm concentrated in the center (Fig. 4*D*, 4*G*, 5*C*). This part of the nervous system, the definitive ganglion, persists through metamorphosis and together with the hypophysis gives rise to the permanent nervous system of the adult.

Visceral ganglion—The visceral ganglion originates in that part of the neural plate that curves toward the left in Stage I. The lumen is obliterated, the large nuclei migrate to the periphery leaving the medulla mass of interlacing fibrils and granules (Fig. 4*D*). The visceral ganglion lies posterior to and ventral to the sensory vesicle. Dorsally where it merges with the sensory ganglion, it exceeds the sensory vesicle in diameter but it gradually diminishes in diameter towards the base of the tail where it is continuous with the neural tube. At the junction there is a slight enlargement called the spinal enlargement (Fig. 4*G*). The neural tube retains its lumen. It runs through the length of the tail to the left of the notochord. In Stage IV a single nerve emerges from the visceral ganglion on its right side just below the hypophysis. It runs anteriorly and sends out branches to the smooth musculature of the mantle.

The Notochord

At the end of the gastrulation period the chordal cells lie under the posterior part of the neural plate. Anteriorly adjacent to them are endodermal cells; dorsally, the potential muscle cells of the right lateral margin of the blastopore; ventro-laterally, the potential muscle cells of the left lateral margin of the blastopore. Posteriorly the chordal cells extend into the rudiment of the tail.

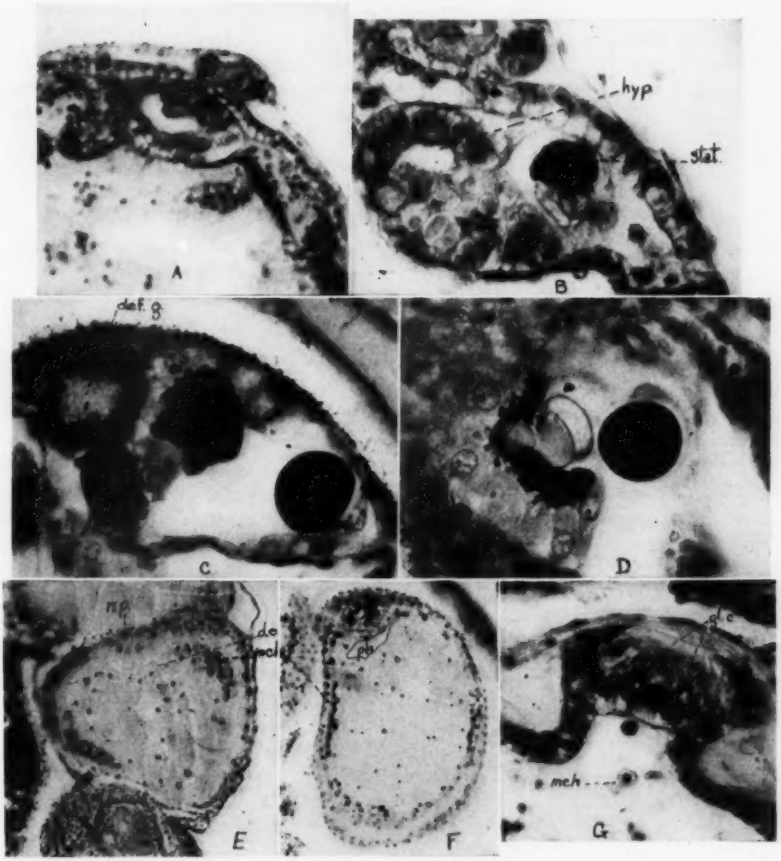


FIGURE 5. *A*. Transverse section corresponding to Figure 4*A*. 225 ×. *B*. Transverse section through brain of Stage III, hypophysis separated from brain vesicle. 650 ×. *C, D*. Sections through sensory vesicle and definitive ganglion of Stage IV; oblique, thus including both sensory organs. 650 ×. *E*. Transverse section through Stage I; anterior region. 150 ×. *F*. Transverse section through early Stage II; neural folds closed. 150 ×. *G*. Longitudinal section through adhesive papilla of Stage III. 650 ×. *d. e.*, definitive endoderm; *def. g.*, definitive ganglion; *gl. c.*, gland cells; *hyp.*, hypophysis; *mch.*, mesenchyme cells; *n. p.*, neural plate; *stat.*, statolith.

Some of the endodermal cells of the yolk mass lie along the right side of the chordal cells and when the tail is constricted from the trunk region these cells form the loose column of caudal endoderm. In Stage IV little of it remains (Fig. 4*C*, 6*B*).

In Stage I the notochordal cells begin to shift in position. They interdigitate into a row of disc-shaped cells occupying the central axis of the short tail. The cells

resemble the endodermal cells of the yolk mass in possessing delicate membranes, nuclei smaller than those of adjoining muscle cells, and yolk granules.

During Stages II and III the notochord elongates as the tail lengthens. The chordal cells lengthen; the inter-cell membranes separate from each other converting them into hour-glass shaped cells with the nucleus resting in the constricted neck between the peripheral masses of protoplasm (Fig. 4*E*).

In Stage IV the cell halves separate completely giving the chord the appearance of a tube with a scalloped lining. The proximal end retains its relationship with the hinder end of the pear-shaped mass of yolk between the atrial cavities and the arms of the digestive tract (Fig. 6*C*, *H*). Distally it corresponds in length to the neural tube and tail muscles.

Muscle cells of the tail

Mesoderm differentiates into three structures of the larva, one of which is restricted to the larval action system, two of which function in both the larval and adult action systems. The former includes the muscles of the tail, the latter the muscles of the mantle and mesenchymatous connective tissue in the body cavity. The asymmetry of the posterior lip of the blastopore at the end of gastrulation (Stage I) places the muscle cells of the right side dorsal to the chordal cells and to the right of the neural plate at its posterior end, the muscle cells of the left side to the left of the posterior neural plate but ventral to the notochord (Fig. 4*C*). Each band is made up of four cells in fairly regular rows.

In Stage II the myoblasts are the most prominent cells in the body because of their size and heavy membranes. Each cell contains a large faintly reticular nucleus with a conspicuous nucleolus. The deeper cytoplasm is grossly reticular and retains an occasional yolk granule (Fig. 6*D*).

In Stage III the peripheral cytoplasm elaborates in its cortex, in a slightly spiral direction, along the longitudinal axis rows of contractile fibrillae composed of minute granules so distributed that they resemble the individual myofibrillae of striated muscle of the higher chordates (Fig. 4*E*, 6*D*). The myofibrillae are continuous from one cell to another throughout the length of the muscle bands. Grave (1921) has described this in the free-swimming tadpole of Amaroecium. The bases of the muscle bands, like that of the notochord in Stage IV, are located well within the posterior part of the trunk just behind the mass of yolk (Fig. 6*H*).

Muscles of the mantle

In the late embryonic period (Stage III) many of the mesenchyme cells located directly under the ectoderm unite end to end to form the smooth fibres of the mantle (Fig. 4*F*). One set of such muscle fibres radiates from each of the siphons. The other set encircles the trunk obliquely from the dorsal to the ventral side.

Mesenchyme of the body cavity

In Stage I two compact lateral masses of mesenchyme cells lie pressed tightly between the nutritive endoderm and shallow ectodermal cells. The one on the right side is disposed more dorsally than the one on the left side (Fig. 5*E*). They extend from the posterior muscle cells towards the anterior end of the body.

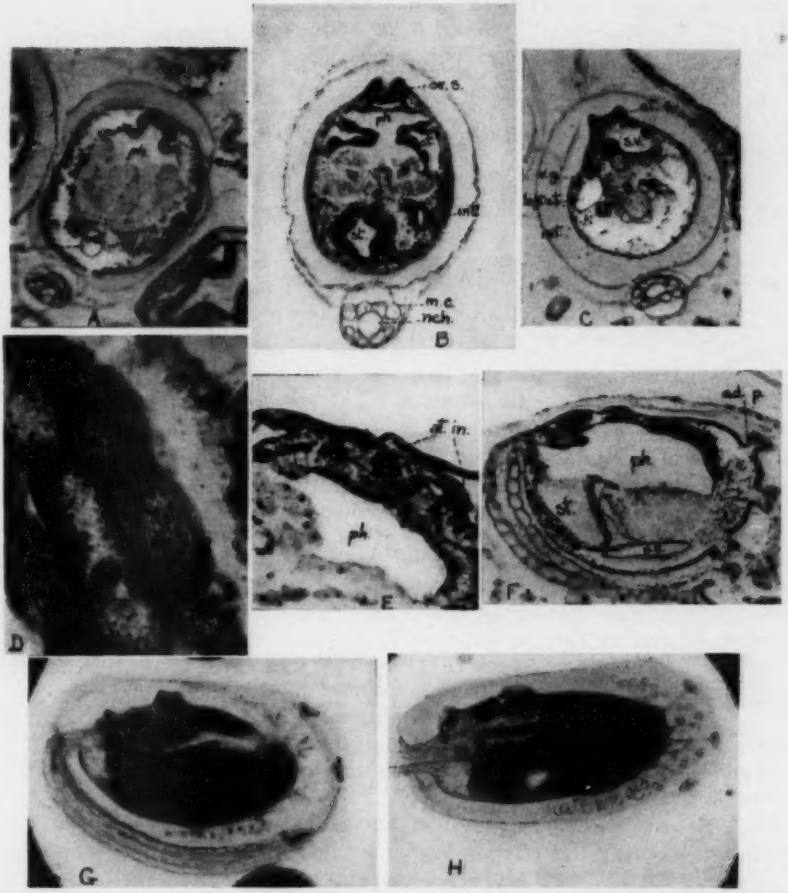


FIGURE 6. *A, B, C.* Transverse sections through tadpoles of Stage IV; *A*, anterior. *B*. In region of oral siphon. *C*. In region of atrial siphon. About 200 ×. *D*. Section through part of muscle band; middle cell through center of muscle cell, lateral cell through peripheral cytoplasm where myofibrillae are formed. About 850 ×. *E*. Transverse section through Stage II to show atrial invaginations. 300 ×. *F*. Longitudinal section through Stage III. About 150 ×. *G*. Tadpole just before hatching, chorion not ruptured. About 250 ×. *H*. Tadpole at hatching. Note insertion of notochord at posterior end of trunk. About 250 ×. *ad. p.*, adhesive papilla; *at.*, atrium; *at. in.*, atrial invagination; *at. s.*, atrial siphon; *end.*, endostyle; *int.*, intestine; *m. c.*, muscle cell; *nch.*, notochord; *or. s.*, oral siphon; *ph.*, pharynx; *p. c.*, pericardial cavity; *st.*, stomach; *s. v.*, sensory vesicle; *v. g.*, visceral ganglion.

In Stage II both masses of cells multiply and spread out under the ectoderm in all directions except posteriorly. A small amount of mesenchyme is found in the tail, probably derived from the cells in the mid-region of the posterior lip of the blastopore. Being crowded together the cells appear angular in section. The nuclei are relatively large (Fig. 4*F*, 5*G*).

During the transition from Stage II to Stage III growth of the body and absorption of the yolk effect a separation between the epithelial cells of the epidermis and the endodermal cells (Fig. 5*F*, 6*F*). As the body cavity enlarges the cells round up, separate from each other, and wander freely about, dividing frequently and eventually filling up all available space except in the area around the base of the tail (Fig. 6*A*, *B*, *C*).

Other mesenchyme cells assume stellate shape and send out long slender strands of protoplasm by means of which they form a reticulum of mesenchymatous tissue. This is the nearest approach to a coelomic epithelium that is found in Tunicates with the possible exception of the perivisceral cavity of Ciona.

The mantle and tunic

The epidermis in Stage I is a layer of thin cells small in surface view dorsally where they adjoin the neural plate, larger towards the ventral body region. In Stage II the cells are of uniformly small size and cuboidal in section except where they invaginate to form the atrium and are columnar in shape. In surface view all present the characteristic polygonal arrangement of epithelial tissue.

During Stage III the protoplasm becomes vacuolated medially, the nuclei being pushed to the periphery where the cytoplasm is more granular (Fig. 5*B*, 6*E*). The epidermal cells grow thinner as development progresses and the inter-cell membranes disappear. When the epidermis has assumed the characteristic appearance of the Tunicate mantle in Stage III it secretes a thick layer of structureless tunic. Occasional cells of the test of the ovum are trapped in the clear tunicin, the greater number, however, being pushed with the test ahead of the tunic (Fig. 6*C*). The tunic is grooved where it is secreted about the tail and when the tail is released, with the disappearance of the test, the groove remains in evidence marking the embryonic position of the tail.

Derivatives of the epidermis

Adhesive papillae—A conspicuous feature of the Amaroecium larva is a vertical row of three adhesive papillae at the anterior end (Fig. 3, 6*F*, *G*, *H*). Each papilla first appears early in Stage III as a local thickening of ectoderm forming a pad of columnar cells. The cells at the periphery of the thickened pad form a stem which increases in length as the tunic thickens, the whole organ becoming goblet-shaped. It retains its connection with the body cavity through its slender hollow stem (Fig. 6*G*, *H*). The papillae extend through the thickness of the tunic and are exposed at its surface. Cells that constitute the functional portion become vacuolated and reticular proximally and toward the center of the cup, where the long cells converge, they produce secretion granules which lodge in the concavity of the papilla (Fig. 5*G*). The bordering epidermis surrounds the disc forming a thin layer over the cup-shaped depression. During the free-swimming life of the larva

the secretion granules are converted into a viscid substance by means of which the tadpole becomes attached. The entire glandular structure is of ectodermal origin. Grave (1921) from his study of the fully formed tadpole supposed that mesenchyme cells gave rise to the glandular portion of the papilla. Mesenchyme cells wander from the body cavity into the hollow stalk but they are not incorporated into its structure. The tail encircling the body crowds the papillae a little to the right of the sagittal plane thus adding to the asymmetry of the larva. The three papillae cannot be homologized with the tactile papillae of Botryllus, which are integral parts of the peripheral nervous system. Here they serve only as gross organs of attachment.

Test vesicles—During Stage III, when the adhesive papillae are differentiating, the test vesicles originate as numerous small ectodermal evaginations in four distinct regions at the anterior end of the trunk. Two groups, separated from each other by the median papilla, are directed forward. The dorsal group is derived from a short ridge extending in the direction of the oral siphon. The ventral group, below the ventral papilla, is derived from a long ridge extending posteriorly through about a third of the length of the trunk (Fig. 5, *6G, H*). The vesicles themselves originate as independent hollow slender projections of the ectoderm. The attached end of each evagination becomes narrow, finally constricting off and severing its connection at the base. Frequently this separation is not effected by the time of hatching of the vesicle still being attached to the epidermis by their stalk-like bases. When detached the slightly pear-shaped vesicle rounds up and becomes a sphere consisting of a single layer of cells which lose their definition on the proximal side where they are extremely thin.

The use of the word "test" in connection with these vesicles is unfortunate. The chorion of the egg of Tunicates is called the test and the cells that either lie freely in the enclosed liquid or are resolved into pavement epithelium are called the test cells. The tunic of the tadpole is a purely ectodermal derivative. The tunic of the adult colonies being the product of secretory activity of these vesicles, the vesicles should, with greater accuracy, be called the "tunic vesicles."

Summary

1. The digestive system of Amaroecium lacks an open archenteron at the end of gastrulation. The pharynx appears as a narrow incision with a thin roof and heavy floor. An oesophageal evagination differentiates into stomach and intestine.

2. Heart and pericardium originate from the floor of the pharynx.

3. Atrium and siphons are ectodermal structures that become associated with the digestive system.

4. The nervous system consists of a sensory vesicle enclosing two sensory masses of pigment, a hypophysis lying beside two sensory ganglion, a visceral ganglion descending laterally to the neural tube which lies to the left of the notochord throughout the length of the tail.

5. The notocord is derived from chordal cells invaginated at gastrulation. Its cells become vacuolated. The notochord is confined to the tail and posteriormost region of the trunk.

6. Muscle cells differentiate from mesodermal cells of the blastoporal margins. Asymmetry of the blastopore places the cells of its right margin dorsal to the noto-

chord, the cells of the left margin ventral to the notochord. Each band of muscle cells consists of four longitudinal rows. Cells separate from the two lateral masses of mesenchyme and move into the body space of the developing tadpole. They give rise to muscles of the mantle.

LITERATURE CITED

CAULLERY, M., 1895. Contribution l'Étude des Ascidies Composeés. *Bull. de la France et de la Belgique*, **27**: 1–158.

CONKLIN, E. G., 1905. Organization and cell lineage of the Ascidian egg. *Jour. Acad. Nat. Sci. Phila.*, **13**: 1–119.

GRAVE, C., 1920. The origin, function and fate of the test vesicles of Amaroucium constellatum. *Anat. Rec.*, **17**: 350.

GRAVE, C., 1921. Amaroucium constellatum—The structure and organization of the tadpole larva. *Jour. Morph.*, **36**: 71–101.

GRAVE, C., 1935. Metamorphosis of Ascidian larvae. *Papers from the Tortugas Laboratory*, **29**: 209–292.

GRAVE, C., 1944. The larva of Styela (Cynthia) partita: Structure, activities and duration of life. *Jour. Morph.*, **75**: 173–190.

HJORT, J., 1896. Germ layer studies based upon the development of Ascidians. *Christiania.*

MAURICE, C. ET M. SCHULGIN, 1884. Embryogenie de l'Amaroecium proliferum (Ascidie composee). *Ann. Sci. Nat.*, (6) **17**: 1–46.

SCOTT, SISTER FLORENCE M., 1945. The developmental history of Amaroecium constellatum. I. Early embryonic development. *Biol. Bull.*, **88**: 126–138.

COMPARATIVE SENSITIVITY OF SPERM AND EGGS TO ULTRAVIOLET RADIATIONS

ARTHUR C. GIESE[1]

Marine Biological Laboratory, Woods Hole, Mass. and Hopkins Marine Station, Pacific Grove, Calif. and Stanford University, California

The sperm of the sea urchin are more sensitive to ultraviolet radiations than the eggs when the effectiveness of the rays is compared by the retardation of cleavage of unexposed eggs fertilized with irradiated sperm on the one hand and of irradiated eggs fertilized with unexposed sperm on the other (Giese, 1939c). It would be interesting to know whether sperm are generally more susceptible to these radiations than eggs; therefore, the experiments were repeated on a number of marine forms. It is also desirable to find an explanation for this differential susceptibility in those cases where it occurs. Insight might be gained by determining action spectra for the sperm and egg, therefore the relative efficiency of action of different wave-lengths of ultraviolet light in retarding cleavage of irradiated eggs and of eggs fertilized with irradiated sperm was determined as described below.

Materials and Methods

Arbacia punctulata, Nereis limbata, Chaetopterus pergamentaceus, and *Mactra* sp. were studied at Woods Hole, Mass. *Strongylocentrotus franciscanus* and *S. purpuratus,* collected at Moss Beach, and *Urechis caupo* collected at Bolinas Bay, California, were used at Stanford University, and *Dendraster excentricus* and *Pateria miniata* were studied at the Hopkins Marine Station, each type of egg being used during the active breeding season.

The methods for studying the eggs were similar to those previously described (Giese, 1938). Except for the work on the action spectrum, the mercury argon discharge tube which emits about 85 per cent of its light at λ 2537 Å was used and the light intensity was measured with a Hanovia Ultraviolet Meter (No. 949). The dishes were kept in running sea water to attain a lower temperature than that of the room. The work on the action spectrum was done with a mercury arc and a natural quartz monochromator and the intensity of the light was measured with a thermopile as in previous studies (Giese, 1938). The eggs were kept in dishes in moist chambers and in a constant temperature room at 15° C.

Sperm were used in dilutions of between 1 : 200 and 1 : 1,000 of the spawn. Such dilution is necessary because in denser suspensions ultraviolet light is completely removed by the sperm first reached. Irradiated sperm lose their fertilizing power rapidly, therefore they must be used soon after exposure (see Hinrichs, 1927, for studies on inactivation).

[1] This work was supported in part by grants from the Rockefeller Foundation. The writer is indebted to Dr. C. Packard, Director of the Marine Biological Laboratory, and to Dr. L. R. Blinks, Director of the Hopkins Marine Station, for making available the facilities and for the many kindnesses extended to the author during the course of this work.

Experimental

Comparison of various eggs

A summary of the general results obtained with all the eggs studied will be found in Table I. Not all the eggs respond to ultraviolet radiations in the same way. Thus cleavage of eggs of Arbacia and Strongylocentrotus is merely slowed up but remains normal after small and medium dosages so that comparisons of the effects of various dosages and wave-lengths is relatively easy. Abnormalities only appear after larger dosages. In Urechis, Nereis, and some of the other eggs the threshold for abnormal development is relatively low. While per cent of abnormal development could be used for analysis of effects of radiations, it would be much more difficult.

It is readily apparent that with regard to ultraviolet susceptibility, there are two types of sperm: in the Echinoderms, especially Arbacia and Strongylocentrotus, the

Table I

Comparative action of ultraviolet radiation[1] on eggs and sperm of various marine animals

Species	Effects on eggs	Effects on sperm
Strongylocentrotus purpuratus	Delay just noticeable after about 100 ergs/mm.²; will develop even after 4,000; after 8,000 ergs/mm.² become quite abnormal.	Noticeable delay[2] even after 10–20 ergs/mm.² Marked retardation as dosage above this is used.
Arbacia punctulata	Noticeable delay after 200 ergs/mm.² but even after 2,000 ergs/mm.² plutei, normal but smaller than controls, develop from eggs. After 4,000–8,000 ergs/mm.² eggs are quite abnormal.	Noticeable delay even after less than 50 ergs/mm.² After 250 ergs still develop larvae but after 500 quite abnormal. Even after 4,000 ergs/mm.² sperm activate eggs.
Dendraster excentricus	Slight delay after 1,600 ergs/mm.²; strong after 6,400; quite abnormal after 25,000 ergs/mm.²	Slight delay after 200 ergs/mm.²; abnormal after 800 ergs/mm².
Urechis caupo	Some delay after 200 ergs/mm.² Marked injury with abnormal cleavage after 5,000 ergs/mm.²	Marked abnormalities after 200 ergs/mm.²
Chaetopterus pergamentaceus	Slight delay only after about 4,000 ergs/mm.²; after 16,000 ergs/mm.² still cleave but much delay and many cytolize.	Slight delay after 2,000 ergs/mm.²; killed after about 8,000–16,000 ergs/mm².
Nereis limbata	Even after 4,000 ergs/mm.² develop with little delay to the trochophore stage; after 8,000 ergs show delayed cleavage.	Slight delay between 4,000–8,000 ergs/mm.² 8,000 kills most sperm.
Mactra sp.	Very slight delay after 500 ergs/mm.²; striking after 4,000–8,000.	Delay after 250 ergs/mm.² and progressive delay thereafter.

[1] The measurements with the Hanovia meter are accurate to about 10 per cent as checked by thermopile measurements in one instance.

[2] Amounting to 15–30 minutes delay at the third cleavage of eggs fertilized with such irradiated sperm. Marked delay means a delay of an hour or more.

sperm are much more sensitive than the eggs; in the worms such as Urechis, Nereis, and Chaetopterus the sperm is slightly if at all more sensitive than the egg, as judged by cleavage delay.

Such a lack of differences in susceptibility of the gametes might be more apparent than real. It is possible that when there is little or no cleavage delay following fertilization of an egg with an irradiated sperm, the sperm may be serving only to activate the egg to haploid parthenogenesis. Eggs of Arbacia and of Chaetopterus were, therefore, fertilized with sperm treated either to a small dosage or to a medium dosage of radiations and at appropriate intervals samples were fixed in Bouin's fluid and stained with iron hematoxylin. Although the preparations were

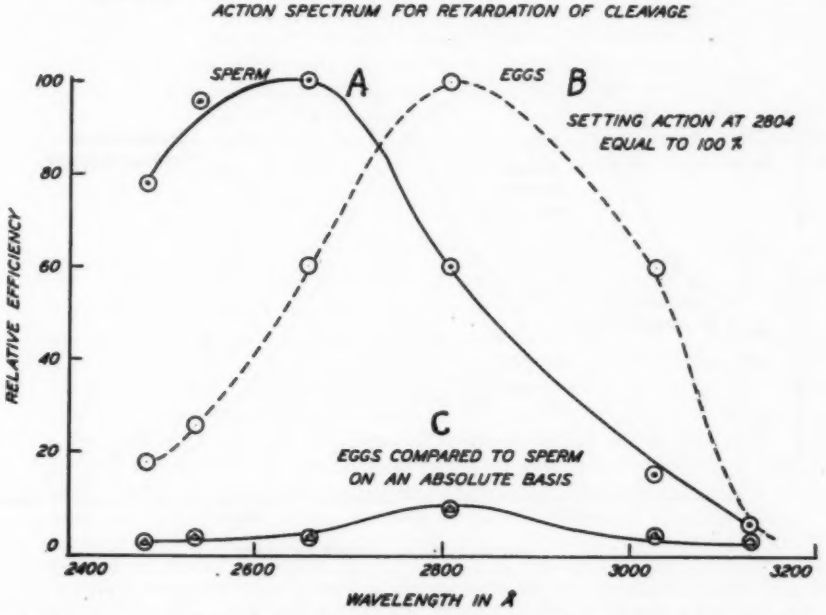


FIGURE 1. Action spectra for retardation of cleavage of eggs fertilized with irradiated sperm at *A* and for irradiated eggs at *C*. At *B* the data for the eggs are compared on a relative basis setting the value at λ 2,804 Å as 100 per cent efficient. See text below.

not entirely satisfactory, evidence for pronuclear fusion was observed in both cases. No lagging or disintegrating sperm were observed in the cytoplasm of either egg. Since neither cytological nor physiological evidence suggests parthenogenesis, it seems likely that for the dosage ranges tested the delayed cleavage follows fusion of the gametic nuclei. The difference between the two types of sperm must lie in some other factor. Possible explanations will be considered in the discussion.

The data in Table I show that the threshold for effects on cleavage is quite different for eggs of different species. Thus Strongylocentrotus, Arbacia, Mactra, and Urechis eggs are retarded after brief exposures to ultraviolet as compared to

Nereis, Chaetopterus, and Dendraster. Whether this is due to mere physical screening by some inert materials in the egg or to differences in concentration of some light sensitive materials is not known.

Action spectra for egg and sperm

If irradiation of the nucleus alone causes retardation of division of the cell, the same action spectrum should be found for egg and sperm; that is, there should be no qualitative difference in effectiveness of different wave-lengths even though the general susceptibility of the sperm is greater. If elements in the cell other than the

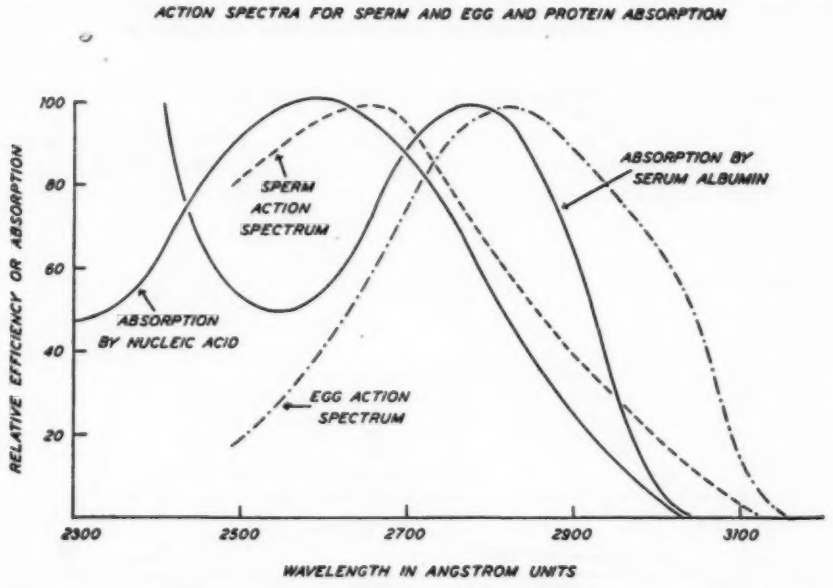


FIGURE 2. Comparison of the action spectra of Figure 1 with absorption spectra of nucleic acid and serum albumin. Data for nuclei acid from Caspersson (1938), for proteins from Smith (1929). Note that the action spectrum for the egg is quite different from the absorption spectrum for albumin at both ends.

nucleus are involved the egg may show an action spectrum different from that of the sperm.

The methods employed for the studies at different wave-lengths are similar to those already described elsewhere (Giese, 1938, 1939c), therefore, only the briefest mention need be made of them. The irradiated eggs are fertilized with normal sperm. The rate of division is then determined by observing for percentage of cleavage every 15 minutes. The times at which the eggs reach the 2, 4, 8, 16, and 32 cell stages are recorded and the number of cleavages is plotted against the time after fertilization and compared with the control. The increase in time required to reach the third cleavage is taken as a measure of the retarding action of the radi-

ations. The retardation is then plotted against dosage. From such curves for each of the wave-lengths the dosage required to bring about a given retardation can be determined. For Figures 1 and 2 the reciprocals of the relative amounts of energy at different wave-lengths required to produce a retardation of division by 1.5 hours were determined. In Figure 1 at *A* and *C* the sperm and egg are compared on this basis and a great difference in susceptibility between the gametes is evident. In *B* the data for the eggs are compared amongst themselves on a relative basis setting the action at λ 2,804 Å as 100 per cent efficient.

The shape of the curves indicates that different materials are being affected in the two cases, since the action spectrum is considered to be a measure of the absorption by the active constituent. To see if the absorbing materials can be identified the absorption spectra for serum albumin and nucleic acid are given in Figure 2. It is apparent that the action spectrum for sperm matches the absorption spectrum for nucleic acid better than the absorption spectrum for albumin; the reverse is true for the action spectrum of the egg. Since the simple proteins and nucleoproteins are the major structural constituents of the cell and none of the other organic or inorganic constituents have very specific absorption, the resemblances while imperfect are indicative of absorption by these two classes of compounds in the action of ultraviolet radiations on the gametes.

Discussion

The occurrence of a differential susceptibility of gametes with the sperm more sensitive to ultraviolet light than the egg as first found in the sea urchin, *Strongylocentrotus purpuratus,* was verified on Arbacia and Dendraster and in preliminary trials on Pateria and *S. franciscanus* but not on Urechis, Chaetopterus, and Nereis. In the latter forms the sperm appears to be only slightly more sensitive than the egg (Table I). The former group of species belongs embryologically to the radially-cleaving, indeterminate egg type, the latter group to the spiral determinate type. In addition, the radial eggs used here are mature or nearly so at the time of shedding whereas the spiral eggs are generally immature. An illustration of the difference in response to ultraviolet light, depending on this difference in organization is seen in the local "burns" occurring in the spiral eggs. Thus a Nereis egg given a unilateral dosage of between 8,000–16,000 ergs/mm.^{2} may develop apparently normally except on the burned surface which appears blistered. A Strongylocentrotus egg on the other hand unless given a large dosage of light will show general effects distributed throughout the retarded egg. However, it is not possible to say which features of the organization account for the difference in sensitivity of the eggs and sperm of the two groups.

One might envisage that in eggs the retarding effects of radiation on cleavage are due to the inactivation, by substances formed during irradiation, of some catalyst which is necessary for the reactions involved in cleavage. In one group of eggs perhaps the catalyst is present in excess of that necessary for a characteristic rate of cleavage, the rate being controlled by some other limiting factor, in the other it is present in just adequate concentration and itself constitutes the limiting factor. Even a considerable dosage of radiations will not reduce the concentration of catalyst below the critical level in the first case but will readily do so in the second. In the first case no cleavage delay would be expected until very large dosages of radi-

ations had been administered, in the second the cleavage should be affected after very small dosages. One would have to assume that irradiated sperm on penetrating unirradiated eggs introduce similar cleavage-inhibiting substances acting on the catalyst as those formed in the irradiated egg. In this case also the effect on cleavage should depend upon the amount of catalyst present in the egg—if in excess, the cleavage should not be easily inhibited, if limiting, the reverse should be true. We should expect both sperm and egg to be relatively insensitive to the radiations in the former and this is found in most spirally cleaving eggs.

Against the above postulation is the fact that the action spectrum for sperm resembles nucleoprotein absorption while for the egg it resembles simple protein absorption indicating two different ultraviolet absorbing materials in the gametes by which the cleavage-retarding effect is produced. It is possible that absorption by both of these types of proteins leads to the formation of toxic photoproducts which inhibit the same catalyst. It is also possible that the toxic substance is much more rapidly formed by the nucleoproteins, but the necessary assumptions strain the imagination.

It should be pointed out that the retardation of the early cleavage is only the initial effect of the radiation. If the delayed effect could be studied we might find that the recovery from injury to the egg would resemble absorption by nucleoprotein, indicating a more lasting injury to the nucleus than to the cytoplasm, as is the case for division of Paramecium (Giese, 1945a). Because the number of cells cannot be satisfactorily determined in the later cleavages such experiments were not attempted with eggs.

The action spectrum obtained for the egg is similar to that observed for "cytoplasmic" effects such as increased time of ciliary reversal, retardation of excystment, immobilization of cilia, and prevention of hatching of eggs. The action spectrum for the sperm resembles that for "nuclear" effects such as recovery of paramecia from sublethal effects, bactericidal and fungicidal effects and the production of mutations (see Giese, 1945b, for references). It is interesting to note the difference between the action spectrum for retardation of cleavage of the egg and for activation studied by Hollaender (1938). In the latter case no action was found until about λ 2,650 Å and the effectiveness of the light increased as the wave-length decreased. The mechanism of action of the light must be different in these two instances. The action spectrum data thus lay the foundation for further analysis of the effect of these radiations upon gametes.

Summary

1. The action spectrum for the retardation of division of eggs fertilized with irradiated sperm resembles the absorption of ultraviolet light by nucleoproteins.

2. The action spectrum for retardation of division of irradiated eggs of the sea urchin resembles absorption by simple proteins like albumin except that at the short wave-length end there is no increase in action at λ 2,483 Å where absorption shows a definite upswing.

3. The absolute amount of energy required to affect division to the same extent by affecting the sperm is very much less than that required to affect eggs.

4. Other Echinoderms tested show a similar difference in susceptibility of eggs and sperm: *S. franciscanus, Arbacia punctulata, Dendraster excentricus,* and *Pateria miniata*.

5. Animals other than Echinoderms tested did not show as striking a difference between susceptibility of eggs and sperm: *Urechis caupo, Mactra* sp., *Chactopterus pergamentaceus,* and *Nereis limbata.*

6. In the eggs listed in paragraph 5, determinations are made more difficult by the tendency for the eggs to show irregular cleavage rather than retarded cleavage as the dosage increases. Such irregular cleavage occurs in Echinoderm eggs as well but the threshold is higher.

7. If both eggs and sperm of the sea urchin are irradiated the effect on the rate of division is less than the sum of the effects which would be expected on each of the gametes alone. However, the percentage of abnormal cleavage greatly increases.

LITERATURE CITED

CASPERSSON, T., 1936. Uber den chemischen Aufbau des Strukturen des Zellkernes. *Skandinav. arch. f. physiol. Suppl., 8 to Vol. 73,* 1–151.

GIESE, A. C., 1938. The effects of ultraviolet radiations of various wavelengths upon cleavage of sea urchin eggs. *Biol. Bull.,* **65**: 238–247.

GIESE, A. C., 1939a. Retardation of early cleavage of Urechis by ultraviolet light. *Physiol. Zool.,* **12**: 319–327.

GIESE, A. C., 1939b. Ultraviolet light and cell division. Effects of λ 2654 and 2804A upon Paramecium caudatum. *J. Cell. Comp. Physiol.,* **13**: 139-150.

GIESE, A. C., 1939c. Ultraviolet radiation and cell division. Nuclear sensitivity: effect of irradiation of sea urchin sperm. *J. Cell. Comp. Physiol.,* **14**: 371-382.

GIESE, A. C., 1945a. The ultraviolet action spectrum for retardation of division of Paramecium. *J. Cell. Comp. Physiol.,* **26**: 47–55.

GIESE, A. C., 1945b. Ultraviolet radiations and life. *Physiol. Zool.,* **18**: 223–250.

HINRICHS, M. A., 1927. Ultraviolet radiation and the fertilizing power of Arbacia sperm. Biol. Bull., **53**: 416–437.

HOLLAENDER, A., 1938. Monochromatic ultraviolet radiation as an activating agent for the eggs of Arbacia punctulata. *Biol. Bull.,* **75**: 248–257.

SMITH, F. C., 1929. The ultraviolet absorption spectra of certain aromatic amino acids and of proteins. *Proc. Roy. Soc. London B,* **104**: 198–205.

OBSERVATIONS ON THE FUNCTIONING OF THE ALIMENTARY SYSTEM OF THE SNAIL LYMNAEA STAGNALIS APPRESSA SAY

MELBOURNE ROMAINE CARRIKER

Zoological Laboratory of the University of Wisconsin, Madison

Introduction

Although records exist of functional studies on the alimentary system of Basommatophora as far back as the early eighteen hundreds, the detailed story of the course and ultimate fate of food in the alimentary tract and the simultaneous movements of the tract is thinly scattered and far from complete. In the more recent emphasis placed on some gastropods because of their importance as vectors of parasites of man, domestic animals, wild game, and fish, it is vitally important that the normal physiology of the system most frequented by these parasites be better known.

It is the purpose of this paper to integrate the previous work on the physiology of the alimentary system of *Lymnaea stagnalis* and allied forms (suborder Basommatophora, order Pulmonata) with original research on the same system in *L. s. appressa* Say. The basic morphological (Carriker, 1945) and histological (Carriker and Bilstad, 1946) studies on this system in *L. s. appressa* have been completed and are in press. All terms used in this research have been described in these two papers.

L. s. appressa has been selected for this research because it is a representative vector and because of its excellent response to laboratory culture, its relatively large size (maximum shell length, 62.5 mm.) as compared with other fresh water pulmonates, its short life cycle, and its relatively thin semitransparent shell and semitransparent tissues. Snails used in the research were cultured entirely in the laboratory. They were grown through many generations in large battery jars and fed on lettuce and cooked "cream of wheat" cereal. The water in the jars was aerated by means of a small Marco air pump (Noland and Carriker, 1946). The original snails were collected in Fox Lake, Wisconsin, in 1939. Parasite-free cultures (especially of trematodes) from the original snails were obtained by the isolation of the egg mass soon after oviposition in separate aquaria. Each new culture was started in this way rendering transmission of infection very improbable. Detailed examination of succeeding generations has not disclosed parasites.

This work was carried out at the University of Wisconsin (1939–1943) under the stimulating guidance of Prof. L. E. Noland, whose advice, encouragement, and friendly cooperation were much appreciated.

Historical Review

Scanty observations on the function of the anterior part of the alimentary tract of *Lymnaea* were given by Semper (1857), Geddes (1879) and Moquin-Tandon (1885); more detailed information was given by Amaudrut (1898), Pieron (1908)

and by Baecker (1932). The stomach region was investigated by Gartenauer (1875), Moquin-Tandon (1885), Colton (1908) and Heidermanns (1924). These experimental contributions of Colton and of Heidermanns, particularly of the latter, are noteworthy. The liver has been the object of most of the physiological work although the research has usually been incidental to that on the stylommatophoran *Helix:* Barfurth (1880, 1881, 1883a and b), Frenzel (1886), Cuénot (1892), Enriques (1901, 1902), Faust (1920), Peczenik (1925) and Krijgsman (1928). Only the investigation of Peczenik is exclusively on *L. stagnalis.*

Experimental Methods and Results

Lymnaea physiological salt solution

The study of the living system has required the development of a physiological salt solution which will approximate the ionic and osmotic balances of the blood of *Lymnaea* more closely than do such commonly used solutions as Ringer's. On the basis of incomplete data given by Duval (1928) on *Lymnaea* and by Bernard and Bonnet (1930) on *Helix* on the molecular concentration of blood, the following solution was developed for *L. s. appressa:*

$NaCl$	2.0 gms. per liter
$NaHCO_3$	2.0 " " "
KH_2PO_4	0.1 " " "
$MgCl_2$	0.3 " " "
$CaCl_2$	0.3 " " "

This solution consists of 0.47 per cent salts and gives a pH of approximately 7.8. After about a week considerable precipitation of $CaCO_3$ occurs, although this seems to have no noticeable effect on the isolated organs. The vas deferens was used in testing the solution and was found superior to the heart for this purpose. The vas deferens, terminal preputium and prostate gland were removed under the physiological salt solution from the cephalic hemocoel without bruising. This portion of the reproductive tract is in part a strong muscular tube which is easily excised and maintains a continuous squirming motion as long as the tissues are alive. It continued squirming for about 66 hours in the solution described above. A Ringer's solution of 0.7 per cent salts keeps it moving for about 12 hours, although at a much reduced rate.

Hydrogen ion concentration

The first work on the estimation of the pH of the alimentary tract of a fresh water snail seems to be that done by A. H. Rosenbloom on *L. s. appressa* in his bachelor's thesis in 1942 (unpublished) in this laboratory. He has kindly consented to the incorporation of his results in this paper. His method was essentially the colorimetric one employed by Yonge (1925): fluids from the various lumina of the alimentary tract of the snails under variable feeding conditions were pressed out onto paraffined plates and thoroughly mixed with indicators (brom-thymol blue, neutral red, and methyl red). The colors were compared with those of indicators freshly prepared in buffered solutions checked on a Coleman pH electrometer. The results are given in Table I:

TABLE I

pH of the contents of various lumina of the alimentary tract of L. s. appressa

Organ	Average pH	Maximum and minimum pH	Number of tests	Number of snails
Buccal cavity	Same as water in external medium.			
Proesophagus	6.9	7.2–6.3	10	10
Postesophagus	7.2	7.6–6.6	10	10
Gizzard and crop	6.4	7.2–6.3	12	12
Pylorus	6.6	7.0–5.8	10	10
Intestine	7.1	7.8–6.2	35	15

Enzymes

Preliminary tests were made for non-purified cathepsin, pepsin, trypsin, and amylase. The tests for the proteinases were made according to the methods of Anson (1938), Bradley (1938) and Folin and Ciocalteu (1927); those on amylase, by the iodine test of Hawk and Bergeim (1937). Semi-micro technics were applied to large numbers of the excised organs.

Maximum catheptic activity (at pH 3) over a ten-day period was found in the liver. That occurring in the buccal mass and gizzard and other portions of the alimentary system was not significant as compared to that in the liver. In an effort to determine to what extent cathepsin might be secreted from the liver, gut fluid from which the amebocytes had been centrifuged was tested. Under the conditions of the experiment, at least, no cathepsin was found in the gut juice. In some tests tryptic activity was found in the salivary glands. A very active amylase, optimum pH 7, was present in the salivary glands and in the liver.

The only investigation of the hydrolytic enzymes of the alimentary system of the Basommatophora reported in the literature is that by Heidermanns (1924). He described a positive test for cellulase present in the digestive juice of the stomach organs (crop, gizzard, and pylorus) of *L. stagnalis*.

Ciliation

Ciliary currents were studied by the injection of fine carmine suspensions in *Lymnaea* physiological salt solution through various portions of the exposed tract, by application of carmine particles to the epithelium of the opened tract and by placing small bits of gut wall in a carmine suspension on an uncovered microscopic slide under high magnification. In some dissections the undisturbed food particles were seen passing through various portions of the excised gut on the natural ciliary currents.

No work has been performed previously on the ciliation of the alimentary system of the Basommatophora. Merton (1923) in his research on the external ciliation of pulmonates included a brief study of the ciliation of the hepatic ducts of *Helix*.

The entire alimentary system of *L. s. appressa*, with the exception of the gizzard and portions of the buccal cavity, is ciliated (see later in this paper), Figures 3, 9, and 11.

Muscular activity

The activity of the alimentary system was observed under binoculars through the transparent walls of normal living young snails and in adult unanesthetized snails opened under *Lymnaea* physiological salt solution. The independent activity of the radula over the odontophore was clearly observed and conclusively verified by watching snails under the binocular under the following conditions: snails deprived of food for a day were placed in a finger bowl of well aerated water to which had been added strips of lettuce (1–2 mm. wide). A Petri dish was floated over the lettuce and the water. As the snails crawled upside down under the glass, feeding on the lettuce, the action of the radula and mouth parts was clearly visible under a strong beam of light.

Sand in the gizzard

In order to check the experiments of Heidermanns (1924) and to add additional information on the role of sand in the comminution of food by the gizzard of *L. s. appressa*, the following experiments were devised.

Sixteen adult snails were placed in each of four aerated aquaria containing a one-half inch mesh wire platform over the bottom. By means of this contrivance the feces were removed from the vicinity of the snails soon after defecation. To three of the aquaria the following foods were added respectively: (1) cooked "cream of wheat," (2) filter paper, and (3) lettuce. (4) No food was added to the fourth tank. (5) A fifth tank was assembled as a control without the wire platform and with lettuce and sand. One snail from each aquarium was killed daily and opened immediately. After ten days the following was disclosed: eight of the forty-three experimental pulmonates contained no sand in the tract, thereby showing that it is possible to rid completely the tracts of a few of the snails of sand; however, there was extensive variation in the ability of the different snails to retain sand. As the quantity of sand in the gut decreased, the snails consumed less food, until in the absence of sand in the tract, no food was ingested and the guts became void of food material and feces. The different diets indicated no significant difference in their respective values as sand eliminators. Sand was found most abundantly in the gizzard lumen, then in decreasing amounts in the crop and retrocurrent passage of the pylorus (anatomical terminology has been described elsewhere, Carriker, 1945). After the quantity of sand in the lumen of the gizzard reached a certain low level, it was retained with surprising tenacity for many days. The material in the fecal pellets of the control snails, particularly of the gizzard residues, was markedly brown and more thoroughly triturated than those of snails with sand-free diets.

In a second set of experiments snails approximately 10 mm. in length were placed in a one-quarter inch mesh wire basket suspended in a large laboratory snail stock tank. The feces, propelled by the sluggish circulation of the water in the tank, passed out of the basket. All lettuce placed in the basket was carefully washed to remove sand. The experiment was continued for several months. In spite of precautions, small quantities of fine sand were always present in the tracts of some of the animals; however, this did not seem to be enough for proper trituration as many of the snails died abnormally at an early age and none reached the normal adult size of the control snails in the tank outside the experimental basket. There

is unquestionably a vital need for the presence of at least a limited quantity of sand in the gizzard of these snails for sufficient breaking down of the food.

These results are in agreement with the findings of Heidermanns (1924) and of Colton (1908). Heidermanns accidently discovered that the only way to entirely remove the sand from a live snail was to cause it to hibernate, in which state it emitted the total contents of the tract. Colton noted that in the presence of sand the plant food was cut to pieces by *L. columella,* but that in the absence of sand it went unmolested.

Digestive cell ingestion

By the use of a method patterned after that of Peczenik (1925) the ingestion of particulate food by the digestive cells was investigated. White of egg was strained through cheese cloth. Carbon (lamp black) was ground into the egg albumen and the mixture was thoroughly beaten. This was steamed to a stiff mass and fed to snails starved for a few days. After feeding commenced, the snails were opened every other day. Indigestible residues within vacuoles in the digestive cells as well as similar residues in the fecal pellets showed the presence of very minute particles of carbon, particles not present in the control snails. The indigestible residues in the digestive cells appeared very similar to the albumen passing down the intestine in the gizzard residues.

Fecal rhythms

Some information was gathered on the rhythms of the liver and of the gizzard by a study of the rate and extent of passage of the various fecal strings. The fecal pellets of a 40 mm. snail were observed daily for twenty-four days. The animal was isolated in a two-liter glass jar over the bottom of which was placed a paraffined one-half inch mesh galvanized metal screen, so that all fecal pellets fell to the bottom of the jar and could not be reconsumed. The mollusc was fed lettuce on which was sufficient sand for the needs of the stomach region. Three egg masses were oviposited by the snail, and it added 2 mm. of shell during the twenty-four day period. Upon dissection at the end of the experiment the animal appeared normal in all respects. For the first ten days the pellets were collected and examined microscopically every few hours during the day; during the latter part of the experiment they were collected every twelve hours. Numerous examinations were made of fecal pellets from the stock snail tanks to corroborate the findings on the experimental snail.

Physiology of the Alimentary Tract

Buccal mass and esophagus

L. s. appressa is primarily an herbivore. In the laboratory it may complete its life cycle on lettuce alone and in its natural state feeds on the aquatic vegetation of its surroundings. Specialization of the alimentary system (Carriker, 1945) has been in keeping with a plant diet. However, animal food is also consumed as has been observed by Walter (1906) and by seven other authors cited by him. Repeatedly in this laboratory *L. s. appressa* has been observed to eat the bodies out of the

shells of dead snails in the aquaria. Biochemical tests disclose the presence of some tryptic activity in the secretion of the salivary glands.

Pieron (1908) has found in *L. auricularia* and *L. stagnalis* that there is a total absence of food discrimination in the buccal mass and that their feeding is a reflex which keeps the radula working most of the time. The only portion of the body showing any discrimination is the anterior surface of the foot which contains faintly sensitive chemoreceptors. In aquaria in this laboratory *L. s. appressa* rasps much of the time, whether on lettuce or over the newly cleaned glass surface of its tank. However it does also pass through regular "resting" periods in which no rasping occurs. In the rasping stroke the radula passes first to one side and then to the other describing a broad feeding track.

Feeding can be followed clearly in normal immature "albino" *L. s. appressa* (a strain with very little dark pigment) feeding on a "cream of wheat" food mixture blackened with lamp black. This can be seen to pass as far as the stomach region. On the protractor stroke the radula cups to an elongated spoon-shaped trowel about one-half the width of the upper mandible, and working against this, cuts out long narrow bits of food. Each denticle is sharp so the concerted action of the numerous denticles on the radula, sliding independently over the odontophore, provides an effective cutting-rasping apparatus. The food bits are pushed back through the dorsal food channel to the rear of the buccal cavity which dilates to receive them. The tip of the radula closely appresses to the dorsal wall of the buccal cavity in its rearward passage, as attested by the jagged pattern of the dorsal chitinous surface. The buccal aperture constricts strongly and rapidly after the receding radula. Some bits of food are dropped and remain in the dorsal food channel for the next rearward swing of the food-laden radula. Several food bits clump in the rear of the buccal cavity prior to being forced down the esophagus. The radula functions principally in cutting pieces of food of suitably small dimensions for convenient transport through the anterior portion of the alimentary tract; it does not triturate the food to any considerable degree.

Only the posterior third of the buccal cavity is ciliated. These cilia and those in the densely ciliated esophagus beat strongly posteriorly, bearing food bits from the rear of the buccal cavity to the crop.

In connection with the functioning of the buccal mass, refer to a previous paper (Carriker, 1945) for the names, origin, and insertion and relations of the muscles and parts of the mass. The muscular activity of the buccal mass is divisible into four major synchronous movements: (1) opening and closing of the oral aperture and consequent spreading and approximation of the mandibles and lips, as well as dilation and contraction of the circular muscles about the anterior portion of the buccal cavity, (2) backward-forward and simultaneous elevator-depressor movements of the odontophore, with some slight turning of the odontophore on its longitudinal axis and some movement to the right and to the left, (3) movement of the radula and radular sac over the cartilage, and (4) backward-forward and simultaneous elevator-depressor movements of the entire buccal mass. Consequently there exist in the buccal mass three intrinsic focal points about which the majority of the muscles radiate: (1) the oral aperture, (2) the odontophoral cartilage, and (3) the radula and the radular sac.

The activity of the odontophore with respect to the remainder of the buccal mass may be arbitrarily divided into four phases, and described as follows: (1) the *quies-*

cent stage in which the odontophore lies at rest in the rear of the buccal cavity with its longitudinal axis in a dorsoventral position. (2) The *protracting stroke* in which the proximal end of the odontophore swings in an arc of about 130° from its basal position to a point where it lies above the plane of the distal end, which then is in a position to pass partly out of the buccal cavity, bringing the radula against the substratum. At the beginning of this stroke the odontophore assumes a horizontal position as a result of the lowering of the distal end by contraction of the dorsal odontophoral flexor muscle, and a simultaneous raising of the proximal end by strong contraction of the posterior jugalis muscle. The oral aperture and the anterior portions of the buccal mass dilate to permit partial protrusion of the odontophore through the mouth; the labial retractors, suboral dilators and dorsomandibular dilators spread the mouth. The extrinsic postventral levators and posterior jugalis further raise the rear of the buccal mass so that the distal tip of the odontophore is directed towards the oral aperture, to which it seems to be guided principally by the action of the dorsal odontophoral flexor muscles. The inframedian radular tensors draw the radula over the distal end of the cartilage to the point where most of the radula outside the radular sac lies on the under side of the horizontally inclined cartilage, and the collostylar hood lies just behind the distal crest of the cartilage. The combined action of the radular sac and cartilage tensors holds the radula tautly drawn over the cartilage in readiness for the rasping stroke. Contraction of the intracartilage tensors adds considerably to the rigidity of the cushion under the radula. As Woodward (1895) points out for *Natalina caffra*, the fibers of the cartilage act in much the same way as the intrinsic muscles of the human tongue and in contraction cause an elongation and consequent slight protrusion of the radula. The pressure of the blood in the odontophoral sinus probably provides further turgidity. Contraction of the extrinsic as well as of the intrinsic protractor muscles brings the odontophore to the substratum. (3) In the *rasping stroke* the distal tip of the odontophore is drawn over the substrate in a licking motion. The radula, independent of the principal motion of the cartilage under it, is itself simultaneously slid quickly backward most of its length over the cartilage by the action of the heavy supralateral and supramedian radular tensor muscles. The odontophore is aided by contraction of the extrinsic preventral levator muscles which pull the anteroventral floor of the buccal cavity forward and upward. As the mouth opens during the previous stroke, the cutting distal margin of the dorsal mandible is turned partly forward by contraction of the dorsomandibular dilators and possibly the posterior jugals. Thus as the radula rasps forward it makes connection with and scrapes past the inner side of the dorsal mandible, much as two jaws would come together, so that the snail when feeding on thin portions of lettuce actually "bites" off pieces with each rasping stroke. It is only when feeding on thicker foods that true "rasping" comes into play. The dorsal mandible is governed by the dorsomandibular approximator muscle. The lateral mandibles afford mechanical protection to the sides of the mouth, and close in medially after the radula and under and behind the dorsal mandible. (4) The *retractor stroke* returns the odontophore to the resting condition, and completes the cycle, by action of the extrinsic retractor muscles and the supralateral and supramedian radular tensors and relaxation of the protractors. The oral aperture is closed after the receding odontophore by action of the labial sphincter and the mandibular approximator muscles; the buccal cavity, by a contraction of the buccal sphincter and related mus-

cles of the walls. In assuming the resting position, the radular sac is depressed behind the cartilage and the radula rests principally behind the vertically arranged cartilage so that the ventral tip of the sac projects slightly below the level of the buccal mass. As observed by Amaudrut (1898) for *Lymnaea*, the ventral wall of the buccal cavity between the esophageal ledge and the collostylar hood is also depressed, forming a slight dilation in front of the esophageal opening. As both the oral aperture and the proesophagus are closed during the retractive stroke of the radula, it is likely that this dilation is instrumental in creating a slight vacuum in front of the esophageal opening which aids in disengaging food particles from the radula. The dilation is caused principally by depression of the radular sac and possibly by contraction of the superior suspensor muscle of the radular sac and the hood tensor muscles.

The proesophagus is limited in its muscular activity to slight peristaltic waves proceeding towards the postesophagus; while the latter undergoes pronounced peristaltic activity in either a forward or a backward direction, dilating broadly and contracting its entire length. In dilation it may become so large as to fill much of the cephalic hemocoel of the expanded mollusc. In expansion it is filled with a reddish fluid from the stomach region and food particles.

In the buccal cavity the food receives generous quantities of fluid from the buccal gland cells, a fluid which is probably mostly mucoid in nature, judging from the positive mucicarmine stain and from negative tests for amylase and trypsin. This does not however preclude the possibility of the presence of other enzymes which were not tested for. As food passes under the openings of the salivary ducts it receives mucus, amylase, trypsin, and possibly other enzymes from the salivary glands.

The proesophagus adds more secretion from buccal glands and mucous cells. The postesophagus functions as a temporary reservoir for the retention of food when the crop is full. Being capable of considerable distension, it may retain larger quantities of food than the crop. Digestion begins in the postesophagus because of enzymatic secretions received from the salivary glands.

Stomach region

Comminution of food particles is completed in the crop, gizzard, and anterior portions of the retrocurrent passage of the pylorus. These three organs act as a unit comparable to a grist-mill. The kneading motion of the anterior and posterior gizzard constrictor muscles and the gizzard lobes over the sand in the lumen provides the grinding action. Food bits forced between the sand are soon crushed to minute particles upon which the digestive enzymes may act more efficiently. Two synchronized movements are present in the gizzard. In the first the anterior and posterior gizzard constrictor muscles alternate smoothly in mild contraction, thus mixing and forcing the contents of the gizzard slowly back and forth; in the second, not as frequent as the first, the bulk of the gizzard compressor muscles contract suddenly and strongly, bringing pressure to bear on the contents of the gizzard. The presence of gritty material in the gizzard of the Lymnaeidae has been noted by many: Cuvier (1817), Wetherby (1879), Whitfield (1882), Moquin-Tandon (1885), Colton (1908), F. C. Baker (1900, 1911), and Heidermanns (1924).

In the crop, all ciliary currents lead to the anterior margin of the right gizzard

pad, those on the left side beating ventrad and over to the right (Fig. 3). Thus fine food material accumulates on the right side of the crop at the anterior edge of the right gizzard lobe. The crop receives food from the postesophagus and forces it into the gizzard lumen. When ample sand is accessible to the animal, the crop and anterior portions of the retrocurrent pyloric passage are both filled with it. The walls of these organs act as mechanical obstructions to the open ends of the gizzard lumen and concentrate the pressure of the gizzard musculature upon the contents. They also cooperate in the muscular activity of the gizzard in a unified kneading and a slow rotation of the gritty contents. The retrocurrent passage returns to the crop those particles which have been dislodged from the gizzard contents by muscular movements of the stomach region. In this fashion the contents of the gizzard undergo thorough comminution and partial digestion before the residues are shunted down the procurrent passage to the prointestine.

The epithelium of the stomach region bears a complicated system of ciliary currents (Figs. 1, 2, 3, 9). Cilia in the procurrent passage direct fine particles from the right ventral side of the gizzard cavity to the prointestine. Those in the retrocurrent passage are directed anteriad towards the left side of the gizzard cavity. The dorsal passage bears what in fixed sections appears to be nothing more than a brush border. Even in carmine suspensions under high magnification no distinct current could be detected in it. The cilia on the ventral fold are divided into two distinct functional areas: those on the right half of the fold beat obliquely posteriad and laterally in the direction of the currents in the procurrent passage; those on the left half, obliquely anterolaterad in the direction of the gizzard and the currents in the retrocurrent passage. The currents on the minor fold whip obliquely anterolaterad; those on the medial half of the major fold pass obliquely anterolaterad; while those on the lateral half of the major fold and those on the medial half of the fold adjacent the hepatic vestibule reach posterolaterad. The ciliary currents in the retrocurrent passage are noticeably faster than those in the procurrent passage. Currents on the atrial corrugations run into the incurrent tubule of the cecum. Thus the pylorus in cross section (Fig. 2) is composed of three channels, each with distinct ciliary currents and of three folds which almost meet centrally and whose

Explanation of Plate I

(All figures concern *L. s. appressa*)

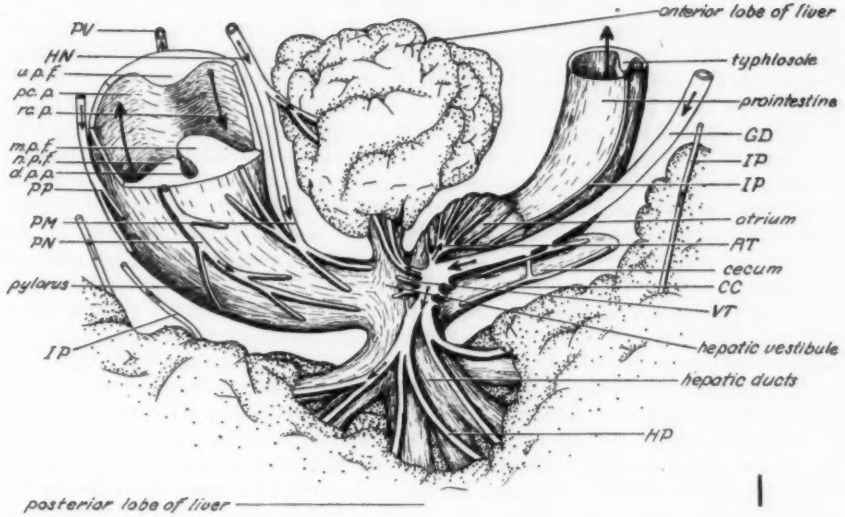
Figure 1. Stereogram of the pylorus, hepatic vestibule, atrium, cecum, anterior portion of prointestine, and liver lobes. The vascularization is stressed. (Small arrows indicate the flow of blood in the arteries; large arrows, the direction of movement of the contents of this part of the tract.) × 6.

Figure 2. Stereogram of cross-section of the pylorus, taken midway between the gizzard and the hepatic vestibule. The stippled surfaces are heavily ciliated. (The small arrows indicate the direction of the ciliary beat; the large arrows, the direction of passage of material in the pylorus. The arrows with broken stems designate the direction of ciliary beat on surfaces behind the folds.) × 25.

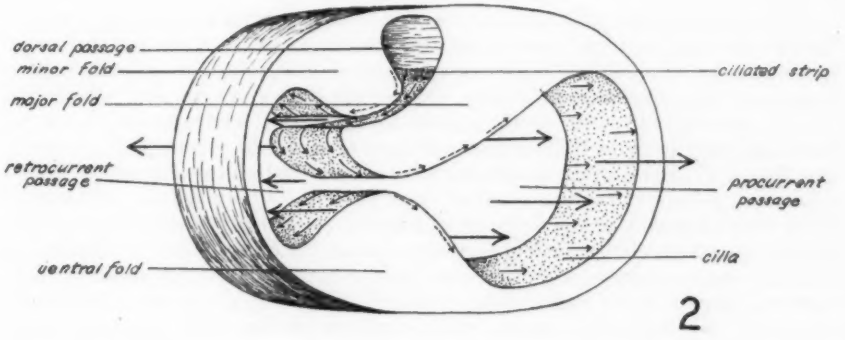
Abbreviations

AT, atrial artery; *CC*, cecal artery; *d.p.p.*, dorsal pyloric passage; *GD*, dorsogastric artery; *HN*, minor hepatic artery; *HP*, prohepatic artery; *IP*, prointestinal artery; *m.p.f.*, major pyloric fold; *n.p.f.*, minor pyloric fold; *pc.p.*, procurrent pyloric passage; *PM*, major pyloric artery; *PN*, minor pyloric artery; *PP*, propyloric artery; *PV*, ventropyloric artery; *rc.p.*, retrocurrent pyloric passage; *v.p.f.*, ventropyloric fold; *VT*, vestibular vascular arborescence.

PLATE I


anterior lobe of liver
typhlosole
prointestine
GD
IP
IP
atrium
AT
cecum
CC
VT
hepatic vestibule
hepatic ducts
HP
posterior lobe of liver
PV
HN
u.p.f.
pc.p.
rc.p.
m.p.f.
r.p.f.
d.p.p.
pp
PM
PN
pylorus
IP

1


dorsal passage
minor fold
major fold
retrocurrent passage
ventral fold
ciliated strip
procurrent passage
cilia

2

ciliary currents pass out of the dorsal into both the procurrent and the retrocurrent passages. The major fold in addition bears a thin longitudinal strip of long cilia at its boundary with the dorsal passage. The major and minor folds in the living animal nearly always touch along their crests, so that the fluid contents of the dorsal passage may pass into the two ventral passages but coarse material from the ventral passage may not pass into the dorsal passage. The juxtaposition of the two folds is continued under the hepatic vestibule, where the folds provide a ventral floor to this chamber. At this point the cilia on the folds direct a powerful current out and away from the vestibule, again preventing the entrance of coarse material into the hepatic ducts and liver.

As discovered for *Helix* by Merton (1923), the corrugations of the larger proximal portions of the hepatic ducts of *L. s. appressa* bear two ciliary countercurrents (Fig. 11): the cilia on the crests of the corrugations are long and beat into the liver, those in the grooves are shorter and pass particles in the direction of the hepatic vestibule and into the incurrent tubule of the cecum. The particles in the grooves are quickly entrapped in mucus secreted there and formed into delicate strings. The currents directed into the liver could be traced with certainty only in the large hepatic ducts, although cilia were observed as far as the peripheral follicles in isolated bits of living liver tissue. Yonge (1936) states that in Mollusca where food passes into the liver and waste material out, the ducts are ciliated in such a way that an inward passage exists on one side and an outward one, on the other. Such counter currents could not be determined in *L. s. appressa*.

In the cecum the cilia on the cecal folds beat off the folds into the tubules (Fig. 9); those in the incurrent tubule pass carmine particles directly to the distal end and around this into the excurrent tubule. Here the cilia beat circumferentially, rotating the contents of the tubule along the longitudinal axis. In the continuation of the excurrent tubule across the pyloric wall the ciliary stream is directed towards the prointestine.

The crop, pylorus, liver, and hepatic ducts are as active as the postesophagus. Besides the usual peristaltic movements, they undergo a series of violent alternating pulsations, here designated *pulsatory movements*, in which the crop, pylorus, hepatic ducts, and liver pulsate successively, forcing the fluid contents slowly back and forth in swirling currents. In the pylorus the pulsations commence at a point between the typhlosole and the atrium and pass towards the gizzard. They are of two types: (1) very strong pulsations in which the entire structure contracts and (2) minor pulsations running over restricted portions of the pylorus. In the liver the pulsations pass as far as the terminal follicles. This marked movement is most vividly observed in bits of living liver tissue under high magnification. Individual cells are seen to move against each other by contraction of the thin muscular connective sheet enveloping each follicle. The pylorus undergoes the most pronounced movements and appears to lead the other organs in activity. The incurrent tubule of the cecum is relatively thin-walled and does not appear to undergo peristaltic activity. The excurrent tubule is thicker-walled and has definite peristaltic movement in the direction of the outlet.

It follows then that one of the important functions of the pylorus is that of a filter chamber, separating the digested and the fine, partly digested food particles from the gross material and sand. This is the conclusion which Heidermanns (1924) also reached when he stated that most of the time sand and gross material

are kept from passing into the liver by the pyloric folds. The major and minor folds remain in close approximation along their crests, leaving a narrow slit between the dorsal and the ventral passages which may be called the *pyloric filter*. The cilia on the folds are well developed and beat away from the dorsal passage. During the pulsatory movements of the stomach region only the finest particles and fluid material are permitted ingress to the liver through this filter. The *pulsatory currents*, as these in the gut lumen may be named, are relatively strong and in their streaming between the sand particles and foot bits in the gizzard cavity dislodge large particles of food. Those which are carried into the pro- and retrocurrent passages and which are too large to pass through the pyloric filter, become entangled in the ciliary currents of the folds and are carried quickly back to the *left* side of the gizzard lumen by way of the retrocurrent passage. The particles carried into the crop on the forward streaming of the contents are soon entangled in the ciliary currents of the crop and conveyed to the *right* side of the gizzard lumen. Here, then, is a delicate adjustment by which the larger particles dislodged from the gizzard contents are equally redistributed for further grinding within the gizzard.

At certain intervals during the day the pulsatory movements appear to cease and a portion of the residual material and sand in the gizzard pass out through the procurrent passage to the prointestine. The propulsion of *gizzard strings* (Fig. 10), as these residues may be named, through the procurrent passage is very slow and mostly by cilia supplemented by slight peristalsis. Cilia were found active throughout all portions of the alimentary tract whenever opened; no cessation of ciliary activity (as occurs in some lamellibranchs during increase of CO_2 concentration) or reversal of beating was observed. During emission of the gizzard string, the large portion of the ventral pyloric fold which partly occludes the gizzard lumen flattens to enlarge the opening. As suggested by Howells (1942) for *Aplysia*, it appears that the shape and position of the pyloric folds in *L. s. appressa* are partly maintained by blood pressure in the sinuses.

To what extent digestion does occur in the postesophagus, crop, gizzard, and pylorus is questionable. As amylase from the liver and from the salivary glands, trypsin from the salivary glands and cellulase, at least, are present in the gut contents, some food may be partly hydrolized. Part of the remaining available food is reduced mechanically to particles small enough for ingestion by the digestive cells of the liver. The amebocytes of the gut also appear to aid in digestion. According to Heidermanns (1924) fats and carbohydrates are absorbed in the pylorus by the ciliated cells.

The pyloric filter permits only minute food particles to pass into the liver. Most of the radular teeth which are discarded continuously from the radula throughout the life of the snail (Carriker, 1943a) and grains of sand as large as 90 μ, by reason of the fact that they are considerably heavier than the lighter food particles of the same dimensions, are carried past the cilia by the force of the pulsatory currents. The larger free food particles, especially of lettuce, are very light and are readily barred by the cilia of the filter. In the proximal portions of the hepatic ducts, because of counter ciliary currents, only the finer particles that fall into the grooves of the corrugations can be carried towards the cecum; thus teeth and larger sand grains are held at this point by the ciliary currents of the crests of the corrugations until sufficient fecal material passes out of the liver to carry them with it.

Ciliation of the crests of the corrugations may play a small role in the conduction

of food material into the follicles of the liver, but probably the principal conveyers are the pulsatory currents. Food in solution and in suspension is thus brought to all the internal surfaces of the liver follicles. Larger particles finding entrance through the filter and too large to remain readily in suspension appear to fall to the ductal epithelium. The smaller of these are soon propelled into the grooves of the corrugations. Liberal quantities of mucus are secreted there, trapping the particles in mucous strings which pass towards the cecum, coalescing as they advance into the larger grooves (Fig. 11). From the incurrent cecal tubule the mucoid strings pass around the distal end of the cecum into the excurrent tubule. There the material receives a further transparent layer of mucoid and cementing material and is rotated into a smooth cylindrical continuous string, here designated the *cecal string* (Fig. 10). This, partly by ciliary action and partly by peristalsis, then passes on into the prointestine across the atrium. In snails feeding on green lettuce the strings are a vivid green because of a heavy accumulation of bits of chlorophyll bearing bodies which become entangled in mucous strings in the hepatic ducts. In gastropods fed on a food containing carbon, the cecal strings are a dense black. In animals on a starvation diet, the cecum continues to pass out cecal strings, just as in the feeding animal, but the strings are a mucoid, transparent, milky-white color and much reduced in diameter. It thus would seem that the function of the grooves in the hepatic corrugations and of the cecum is to collect and eliminate those fine particles which pass through the pyloric filter but which are too large to be engulfed by the digestive cells and which are thus mechanically eliminated by a "supplementary filter." Cecal strings pass out continuously, apparently at the same uniform rate and without apparent interruption. They provide a kind of "time clock" by which the rate of passage of the gizzard strings and the residues from the liver can be compared (Fig. 10).

Explanation of Plate 11

(All figures concern *L. s. appressa*)

Figure 3. Ciliation currents of the postesophagus, crop, gizzard, pylorus, hepatic vestibule, atrium, and anterior portion of prointestine. The tract has been slit ventrally and spread. × 6.

Figure 4. Irregular blue-green excretion bodies (in vacuoles) taken from the liver string. × 500.

Figure 5. Smooth blue-green, or brown, excretion bodies (in vacuoles) taken from the liver string. × 500.

Figure 6. "Signet" excretion body (in vacuole) appearing in the liver strings. × 500.

Figure 7. Clear nodules found in the liver strings which when pressed out under the cover slip display their crystalline nature. They dissolve in dilute HCl and seem very similar to the calciferous concretions of the vesicular cells of the connective tissue. × 500.

Figure 8. Indigestible residues from digestive cell (in vacuole), found abundantly in liver strings. × 500.

Figure 9. Ciliation currents of the cecum, which has been opened along the incurrent cecal tubule and spread flat. × 6.

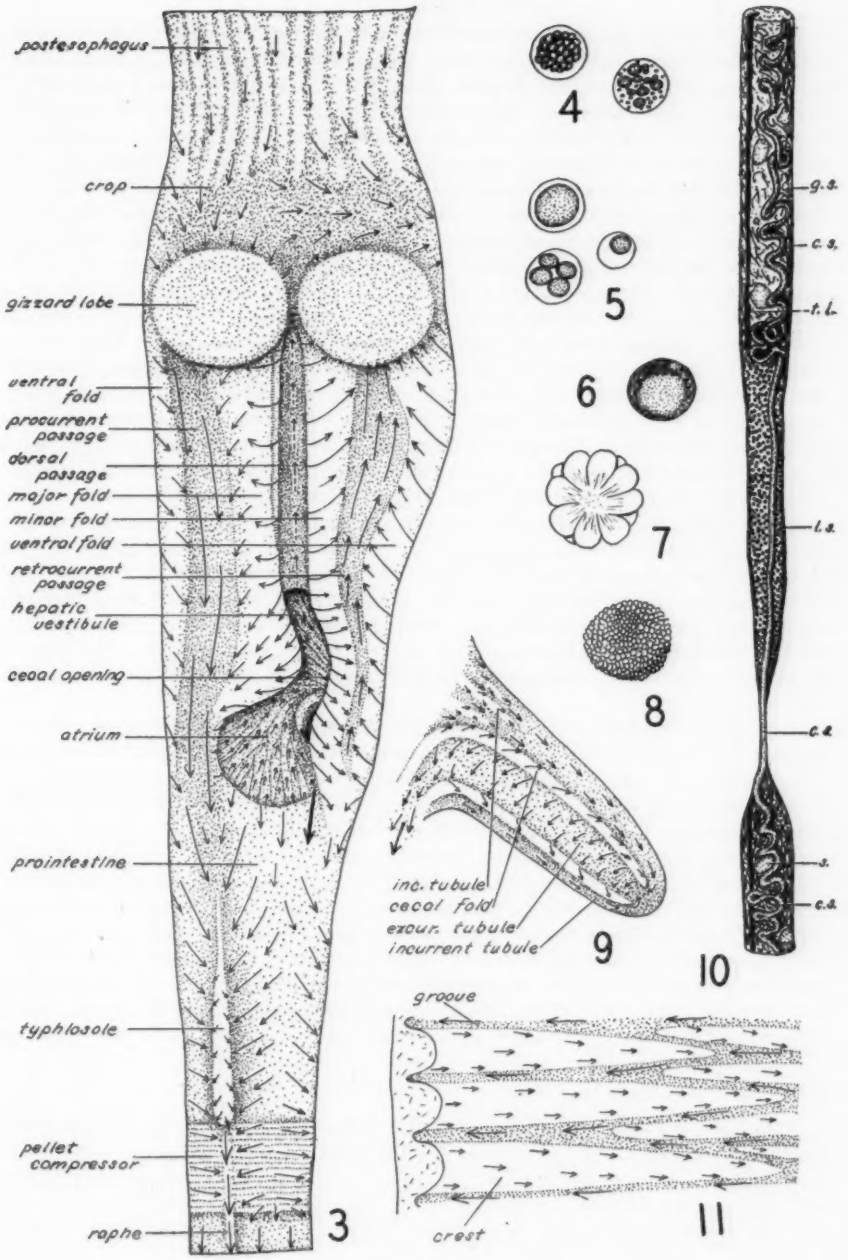
Figure 10. Typical fecal pellet, showing the gizzard, liver and cecal strings, and the impression of the typhlosole in the pellet. × 6.

Figure 11. Portion of the corrugated epithelium of the hepatic duct, taken at the opening of the duct into the hepatic vestibule. (Large arrows indicate the direction of the ciliary currents in the grooves; the small arrows, that on the crests of the corrugations.) × 50.

Abbreviations

c.s., cecal string; *excur. tubule*, excurrent tubule; *g.s.*, gizzard string; *inc. tubule*, incurrent tubule; *l.s.*, liver string; *s.*, sand; *t.i.*, impression of typhlosole in fecal pellet.

PLATE II


postesophagus
crop
gizzard lobe
ventral fold
procurrent passage
dorsal passage
major fold
minor fold
ventral fold
retrocurrent passage
hepatic vestibule
cecal opening
atrium
prointestine
typhlosole
pellet compressor
raphe
3
4
5
6
7
8
g.s.
c.s.
t.l.
l.s.
c.s.
s.
c.s.
10
inc. tubule
cecal fold
excur. tubule
incurrent tubule
9
groove
crest
11

The excretory bodies and indigestible residues in the liver are voided periodically. These are passed simultaneously in minute mucous strings from all parts of the liver towards the central hepatic ducts, there converging into larger strings which pass in the direction of the hepatic vestibule. At the proximal end of the hepatic ducts this material fills most of the main duct. The combined currents in the grooves of the corrugations appear to exert a stronger force than those on the crests, so forcing the waste material directly into the hepatic vestibule (Fig. 11). There it is caught by the outward flowing ciliary currents on the major and minor pyloric folds and passed rapidly into the prointestine. The excretory bodies and indigestible residues passing from both lobes of the liver are compressed in the hepatic vestibule into one bulky string which is distinct from the cecal and from the gizzard string and may be called the *liver string* (Fig. 10). It is drawn out of the liver at the same rate as the cecal string passes out of the ceum. Both strings are usually found parallel to each other and uncoiled in the fecal pellets. The gizzard string, on the other hand, passes out much more slowly so that the cecal string occurs loosely and abundantly coiled therein (Fig. 10). A lapse of time seems to occur between the exit of the gizzard string and that of the liver string, as indicated by a conspicuous coiling of the cecal string between the last portion of the gizzard string and the forward end of the liver string. The gizzard string follows the liver string immediately, as indicated by no noticeable coiling of the cecal string between the two. There is also some evidence that, as the liver string is drawn from the liver, the pulsations of the stomach region cease. In animals opened for physiological observation of the tract, the stomach region was never pulsating when the liver strings were passing out of the liver. This is desirable to prevent the dismemberment of the strings and their mixing with food material brought into the liver by the pulsatory currents. The merger of the strings in the prointestine produces the fecal pellets.

The pylorus is composed of a complicated system of folds and passages, it is innervated by a pair of complex nerve plexuses and a nerve net, and all of the parts are exceptionally well vascularized. Functionally there is present in this portion of the tract an intricate system of counter ciliary currents and synchronized muscular movements, as well as partial vascular control of the folds. The pylorus is thus well equipped to convey digestive fluids from the liver to the gizzard and crop, to bear digested and semi-digested particles into the liver from the gizzard, to exclude large sand and other large particulate matter from the liver and transfer such residues to the prointestine, to receive waste material from the liver and transport it to the intestine, to act in conjunction with the cecum, liver, and hepatic ducts in shunting a continuous string of residual particles from the walls of these organs into the prointestine, to secrete fluids (of unknown nature) and finally to absorb fats and carbohydrates.

Liver

The liver is probably the most important organ of digestion in the alimentary system of the gastropods. Peczenik (1925) shows, as has been indicated in this work also in feeding experiments, that such proteins as egg albumen are engulfed and digested intracellularly in the digestive cells, and the indigestible residues are cast out in vacuoles. Krijgsman (1928) believes that digestive cells in *Lymnaea*

are also secretory as well as absorptive, as he has often observed numerous typical secretion granules in the liver cells of starved snails. Biochemical tests indicate that the greatest catheptic activity of the snail body is localized in the liver, yet none of this activity has been found in the fluid of the gut. This is in keeping with catheptic systems in other animals in which the enzyme has been shown to exist entirely as an intracellular protease. Hurst (1927) writes that in *Physa* fat and glycogen are stored in the digestive cells. Fat was also found in the lime cells of *Helix* by Grünbaum (1913). The problem of *what size* of food particle is engulfed through the distal membrane of the digestive cells is still an open question. It is likely, as indicated by the work of Krijgsman (1925, 1928) on *Helix*, that the lime cells function in storing and in periodically secreting a buffering agent which adjusts the pH of the gut juice; this point has not been investigated in *L. s. appressa*. The mucous cells of the liver provide the mucus utilized in the binding of the indigestible residues and the excretory bodies into the liver strings.

Amebocytes were found in varying numbers in the contents of the lumina of the liver, postesophagus, gizzard, and pylorus. These were similar to those seen in the blood. In some instances those in the gut contained fecal vacuoles so large as to force the cell into a peripheral lobate ring.

Rhythmic activity of the liver is suggested by inspection of sectioned liver tissue, of fecal pellets and of the living organ in various phases of its activity. Pulsatory movements of the stomach region are apparently interrupted only during the passage of liver strings and of gizzard strings. This may explain why smaller hepatic excretory bodies occur in the upper pylorus, gizzard, crop, and postesophagus in such insignificant numbers. If the pulsatory currents persisted during the elimination of the liver residues one would expect to find liver string detritus scattered over the gut in as great profusion as in the liver, along with the reddish colored secretions from the liver.

The inclusion bodies of the digestive cells of *L. s. appressa* have been studied in detail in the living cells of normally feeding snails, starved snails, snails fed on special diets and in preserved tissue sections. The egested bodies have been followed in the fecal pellets over a period of weeks. The results of the study clearly indicate the presence in the digestive cells of excretion bodies, of indigestible residues and of secretion in separate vacuoles.

Figure 8 illustrates a vacuole from the digestive cells which is filled with indigestible particles. These vacuoles measure 12 to 25 μ in diameter. In snails feeding on lettuce the contents are colored a greenish brown to dark brown and are composed of minute irregular particles, some of the larger ones of which measure about 3 μ in diameter. In the digestive cells they occur one per cell and in varying stages of particulate concentration. These constitute the bulk of the liver strings and retain their identity in fecal pellets which have been voided for several days.

The secretion granules are clearly evident in preserved histological sections stained with iron hematoxylin, especially grouped towards the distal area of the cell. Larger granules measure as much as 4 μ in diameter.

The excretion vacuoles (Figs. 4, 5, 6) when in the cells may measure as much as 25 μ in diameter, but in the fecal pellets have shrunk somewhat. In the living cells excretion bodies are found in variable form and color and are best observed when the cells are slowly pressed out under a cover slip as the fluids evaporate. The cell contents then pass rolling and turning from the ruptured cells, exposing the

different surfaces of the inclusions. There is one series in which the vacuoles range from small to large vacuoles containing variable numbers and sizes of minute blue-green, translucent, many-angled particles. The smaller particles are in constant Brownian movement, dancing around like a swarm of bees, and indicating the low viscosity of the fluids in the vacuoles (Fig. 4). In a second series the same variation in size of the vacuole is encountered but the blue-green bodies are present in groups of only one to four per vacuole and are spherical and smooth (Fig. 5). In a third series the vacuoles and bodies are identical in form to the second series, but the color of the bodies varies from a light brown to a dark solid brown. The largest of these bodies are sometimes found free of the vacuoles. When compressed under a cover slip they spread with a flowing viscous movement, much as a drop of heavy molasses spreads when pressed between two smooth surfaces. In the fecal pellets these vacuoles are usually found varying in diameter from 3 to 15 μ, and the vacuole membrane presses closely around the excretion body. A fourth type of excretion body is found which varies in diameter from 12 to 18 μ, is colored a dark brown with a smooth center and possesses a periphery of irregular markings, such that the body resembles a signet ring (Fig. 6). The excretion bodies described above are present principally in the liver strings, and only in negligible numbers in the cecal strings. The "browns" and "signets," particularly, stain with methylene blue and neutral red and do not dissolve in strong HCl. The different types described are not all present in any liver string in equal abundance at any one time, but vary independently, in a sequence which did not seem significant. Because of the transitional stages between some of these excretion bodies it is probable that they are all different phases of the same type of metabolic excretion; but the method of their formation is still a puzzle.

Intestine and rectum

Cilia on the typhlosole beat towards the lateral sides of the typhlosole (Fig. 3); those over the prointestine around the typhlosole beat circumferentially and somewhat obliquely from the dorsal to the ventral sides in a symmetrical pattern. The division of the currents occurs along the dorsal line of the prointestine. Over the pellet-compressor the cilia beat transversely across the intestine. The raphe bears a strong current which streams directly posteriad. Thus in the pellet-forming region, through ciliation and muscular movement, loose particles are gathered, rolled inward about the typhlosole and folded into a compact pellet. Strong ciliary currents in the remainder of the intestine and rectum are limited almost entirely to the costae, raphe, and pseudoraphe; cilia of the intercostal surfaces are relatively short and weak. Peristaltic activity is evident throughout the intestine and rectum, being noticeably strongest in the early portions of the prointestine, just behind the pellet-compressor.

Abundant vascularization of the prointestine, in contrast to the relatively poor vascularization of the esophagus, suggests that this region of the intestine may also function in the absorption of food and water.

Consolidation of the cecal and liver strings occurs at the hepatic vestibule; of the gizzard residues and cecal string, in the pellet-forming region. The cecal string as it is moulded in the cecum is already a smooth well cemented string and undergoes no further change as it is forced continuously across the outer margin of the atrium.

The liver string, characterized by a fine dark brown mottling and almost as well concentrated as the cecal string, receives a final transparent envelope of cementing fluid which binds the cecal string to it (Fig. 10).

The chief function of the pellet-forming region is that of consolidating and cementing the loose straggling gizzard residues which constitute by far the greatest bulk of the fecal pellet. The large numbers of mucous cells, basophilic flask cells and basal secreting cells about the pellet-forming region are indicative of the large quantities of cementing substance secreted during the moulding of the pellets. By means of ciliary streams and constriction of the tube at the pellet-forming region the gizzard residues are pressed into pellets, and the cecal strings, lying loosely

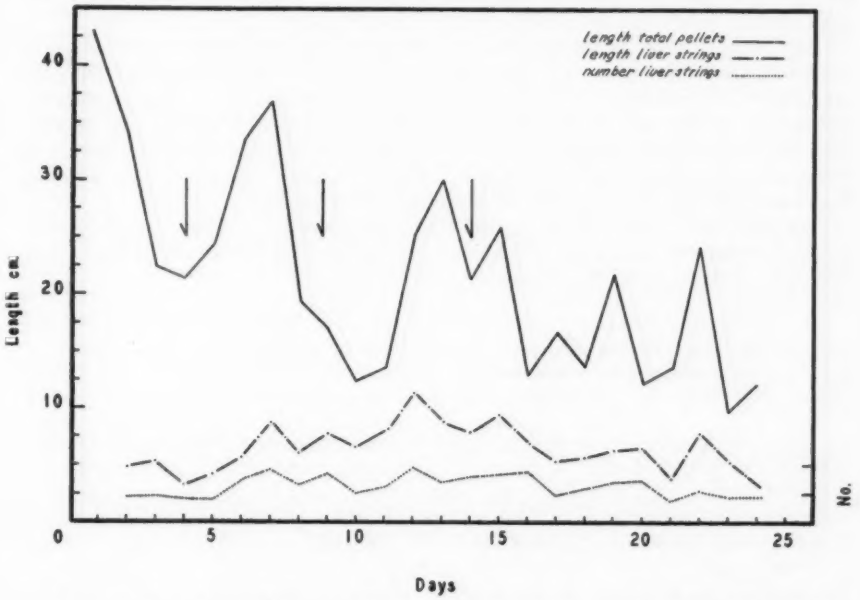


FIGURE 1. Length in millimeters of the liver and gizzard strings and number of liver strings of the fecal pellets, calculated on a twenty-four hour basis. These were voided in a period of twenty-four days by a forty millimeter *L. s. appressa*. The vertical arrows indicate the time at which egg masses were oviposited.

coiled in these residues, are simultaneously incorporated in the pellets. These are then forced out of the pellet-forming region by ciliary activity and by strong peristaltic movements which are noticeably stronger immediately behind the pellet-compressor. Peristaltic activity gradually diminishes in the direction of the anus. The conspicuous impression of the typhlosole remains in the fecal pellet, particularly in the gizzard string portion, as long after defecation as the pellet retains its form. Moore (1931) has found variable patterns in the fecal pellets of different Gastropoda and points out the importance of identification of animals by means of their pellets. A most striking fact about fecal pellet formation is the extreme com-

pleteness with which fecal material is compressed and cemented. This presumably prevents fouling of any portion of the tract.

For any given snail the diameter of the gizzard string portion of the fecal pellet is constant, varying principally with the size of the snail. The liver string varies in diameter from that of the gizzard string to that of the fecal string. Figure 1 indicates for a forty millimeter snail over a period of twenty-four days the rate and extent of voidance of fecal pellets. For the tabulation of this data the fecal pellets were collected daily and arranged end to end under the binoculars and measured to the nearest millimeter. The measurements given indicate only the lengths of the gizzard and liver strings, as the cecal string generally occurs embedded in the first two strings. The diameter of the gizzard string is reliably constant; that of the liver, less so.

Most conspicuous is the fact that the quantity of fecal pellets voided daily is quite variable from day to day. The quantity of gizzard strings fluctuates far more erratically than does that of the liver strings, indicating that the volume of material utilized by the liver is more constant than that which may pass through the gizzard. The number of liver strings is a more conservative indicator than the length of strings, and is probably not as accurate. Passage of food through the gizzard, and thus food consumption, seems to diminish during oviposition.

As indicated by the following data, feces were voided in about equal quantity day and night, with just a slight daily increase, over a period of twenty days (9 P.M. to 9 A.M., and 9 A.M. to 9 P.M., respectively):

Pellets	Night	Day
Total length of pellets, mm.	1,987	2,134
Total length of liver strings, mm.	530	588
Total number of liver strings	110	113

The total length of fecal pellets passed in the twenty-four days was 5,645 mm.; and the total length of liver strings, 1,491 mm., was passed in 289 liver strings, giving an average length of 5.1 mm. per liver string. Actually the liver strings varied in length from one to 10 mm. The average calculated length of fecal pellets passed in twenty-four hours was 235 mm.; of liver strings, 62 mm. In a normally feeding snail the sequence of the liver strings with the gizzard strings was always one of alternation. Liver strings do not generally mix with the gizzard strings. Gizzard strings as long as 52 mm. were found connecting liver strings. Three typical series of fecal pellets taken from days one, two, and three on Figure 1 are given below. The liver and gizzard strings are represented by the lengths in millimeters of the strings in the order of their elimination; the figures for lengths of the gizzard strings are italicized. The total time for elimination of the pellets is given to the right in parenthesis:

(1) 6 *40* 7 *33* 7 *11* 6 *44* 5 (5 hrs. 15 mins.)
(2) *48* 7 *52* 8 *13* 4 *50* 5 *38* 6 (10 hrs. 15 mins.)
(3) *20* 7 *8* 7 *22* 6 *29* 9 *24* 3 (10 hrs. 30 mins.)

As indicated by the curve for total fecal pellets in Figure 1 and by the lengths of the gizzard strings in the series above, consumption of food appeared to follow an alternating heavy and light cycle.

In snails deprived of food the elimination of the gizzard strings ceased and liver strings then became connected only by slender lengths of cecal strings. When starvation had continued for ten or more days nothing but delicate white cecal strings and a few much reduced liver strings containing metabolic excretion bodies were found in the intestine.

A. H. Rosenbloom (unpublished bachelor's thesis, 1942) by feeding colored food to *L. s. appressa* at different times through a period of a month found that in normally feeding snails of approximately forty millimeters shell length the minimum time for the passage of food from the mouth to the anus was two hours and twenty minutes; in snails previously starved for a week, five hours and fifty minutes. He found also that previously starved snails feed for a longer consecutive time than do normally feeding snails. The present investigation shows clearly that the alimentary system becomes completely emptied of food a few days after starvation commences. Considerably more food and a longer time are required for a starved animal to fill the alimentary tract with food to the point where fecal material is voided than for a normally feeding snail.

The rhythm of passage of liver strings is in keeping with the rhythm of the liver itself in which all digestive cells appear to assimilate food together and discharge indigestible residues simultaneously. This cycle, as indicated by the passage of liver strings, is not completely unvarying, because the number of liver strings discharged daily varied approximately from eight to nineteen. Thus the interval between the discharge of liver residues, probably the time during which the liver was digesting food, varied in this experiment from seventy-five minutes to three hours. It is possible that oviposition (Fig. 1) may account for some of the variability.

There seems to be nothing in the literature concerning fecal cycles in the Gastropoda. Some few scattered observations are reported on the length of the fecal pellets. For example, Heidermanns (1924) writes that a 48 mm. *L. stagnalis* with a 90 mm. intestine, eliminated 120 mm. of feces in 24 hours.

The long intestine is characteristic of the herbivorous snail nutrition of *L. s. appressa*. One of the most striking facts about the functioning of the alimentary system is the meticulous care with which all loose particles are collected and properly disposed of, in this way serving as a highly efficient sanitation system. The fecal pellets receive additional external layers of cementing material as they pass down the length of the intestine and rectum. The pH of the intestine is slightly more alkaline than that in the stomach region. As pointed out by Yonge (1935) mucus is an amphoteric protein whose viscosity is augmented by higher pH, thus more efficient consolidation of the feces occurs. Elimination of the fecal pellets through the anus is a fairly rapid and uniform process. The strong anal sphincter muscle remains tightly contracted except during defecation. Fecal pellets, being slightly heavier than water, settle slowly to the bottom of the aquaria. The marked efficiency of the mucoid coating over the feces is indicated by the extended period after defecation that pellets retain their identity. Thus it would seem that the alimentary system has not only become specialized in the maintenance of hygienic conditions within the system, but also in furthering a healthy external environment.

Fecal pellets are ingested by snails even in the presence of fresh food and the animals appear to derive some nourishment from them. It is to be recalled that the gizzard is not a thoroughly efficient grinding mechanism and in many cases,

particularly in the absence of sufficient fine sand, considerable unused available food passes out in the gizzard strings.

Discussion

The question as to whether the radula slides over the cartilage independent of cartilage activity has been a favorite point of academic controversy with certain malacologists for some time (in Lymnaeidae see Geddes, 1879; Amaudrut, 1898; and Pelseneer, 1935; in the Stenoglossa, a review: Carriker, 1943b). In *L. s. appressa* (and possibly in the majority of snails carefully investigated) there is no question but that the principal activity of the radula is that effected by the action of the cartilage and muscles under it, and a sliding of the total radula over the cartilage independent of the movement of the cartilage.

A study of the movements of the gut in *L. s. appressa* suggests that rather than the presence of different pH in the different portions of the gut, the pH may vary with the rhythms and secretions of the liver, the secretions of the salivary glands, the secretions of the unicellular glands of the gut wall and with feeding. It is quite unlikely that with the constant mixing of the gut contents as a result of the pulsatory movements at certain periods, the pH would vary markedly in the different lumina of the tract at any time. The wide range obtained between the maximum and the minimum pH's and the insignificant variation of the maximum and of the minimum pH's is in keeping with this suggestion. The partial isolation of the intestine from the movements of the stomach region is in keeping with the slightly higher pH found in the intestinal lumen.

The complexity and abundance of nervous tissues about the stomach region suggests a possible nervous control of the movements of the stomach region and of the liver. In its muscular structure there is no doubt that the buccal mass is the most complex organ in the alimentary system; functionally it appears that the region in and about the pylorus is the most intricate. The dense ramifications of blood vessels, the presence of two nerve plexuses, the intricate series of folds and the complicated ciliary streams in this region lend credence to this postulation.

Heidermanns (1924) has opened the question of the function of sand in the basommatophoran gizzard in his comparative study of *Ancylus, Planorbis, Physa, Lymnaea* and certain stylommatophorans. He points out that in land pulmonates the flaring portion of the esophagus is called the stomach, whereas in the aquatic pulmonates the esophagus is normal and the stomach has become differentiated into the crop, gizzard and pylorus. Thus the Stylommatophora have no organs that could properly be homologized with the stomach of the Basommatophora. The gizzard and, with few exceptions, sand in the tract are absent from the land pulmonates. The gizzard, he states, reaches its peak of specialization in *L. stagnalis* and probably rose by reason of the ingestion of sand with food. He observed that in all Basommatophora the gizzard originates in front of the first flexure of the gut, apparently as a muscular band whose primitive function was to dispose of sand masses tending to congest there. This primitive type of gizzard is exemplified by that of *Ancylus* and the intermediate type by that of *Planorbis*. Heidermanns in support of his theory of the origin of the gizzard through a specialization of a primordial portion of undifferentiated gut, attempted to show modification of the gizzard in one snail generation by the use of various diets. As might be anticipated, he got no significant structural changes.

The fact that *Lymnaea* possesses the gizzard grinding mill may explain the observation stressed by Heidermanns that the cellulase of this snail is less active than that of *Helix* which has not developed a gizzard and consequently needs a strong cellulase for the hydrolysis of the cell walls of plant food consumed.

There is striking similarity in the functioning of the alimentary tract of the herbivore *Onchidella celtica,* ably presented by Fretter (1943) in a recent paper, and that of *L. s. appressa.* Perhaps this similarity is not to be wondered at when, as Fretter writes, "Many of the features which the Onchidiidae share with the pulmonates may be attributed to the close origin of the two groups, the similarity of their diet and their air-breathing habit."

Summary

1. A balanced physiological salt solution was developed which maintains contractions of the vas deferens for approximately 66 hours.

2. Cathepsin was found in greatest concentration in the liver and no activity could be ascertained in the gut fluids. Some trypsin was indicated in the salivary glands. Amylase showed greatest activity in the salivary glands and the liver.

3. Muscular activity of the alimentary system involves the manipulation of the mouth parts in the buccal mass, peristalsis in the remainder of the tract, marked pulsatory movements of the postesophagus, crop, pylorus and liver, and a kneading motion of the gizzard. The radula is moved principally by the action of the odontophore but also operates independently of it.

4. The entire alimentary system, with the exception of the gizzard and parts of the buccal cavity, is ciliated. The cilia show definite directional streams which function in propelling food particles, in sorting food and in consolidating fine refuse particles with the aid of mucoid substances.

5. Sand is consumed normally by the snail and is necessary for the proper functioning of the gizzard in the crushing of food particles. Very little trituration is performed by the mouth parts.

6. The pylorus is composed of a complicated system of folds and passages and counter ciliary currents and functions as a filter which permits only the soluble and the finer food particles to pass into the liver. It shunts the undigested residues from the gizzard into the prointestine.

7. In the liver the digestive cells function in secretion, assimilation, intracellular digestion and excretion. The indigestible foods and the excretory products, as variably shaped and colored inclusion bodies, are eliminated in vacuoles.

8. The cecum functions in collecting the finer residues from the liver and forces them in a continuous string into the prointestine.

9. The residual material coming from the gizzard, liver and cecum is characteristic for each organ and is readily identified as distinct in the fecal pellet.

10. The prointestine is specialized in the final consolidation of gizzard, liver and cecal strings with the aid of cementing substances secreted by the basophilic flask cells and the basal cells.

11. The rhythmic nature of the liver is disclosed principally by a study of the fecal pellets.

12. *L. s. appressa* is an herbivore. Food bits are cut away by the radula and swallowed. In the buccal cavity the food receives mucus from the buccal gland

cells, mucous cells and the salivaries and enzymes from the latter. Temporary storage and initial digestion occur in the postesophagus. Digestive fluids pass up from the liver in the pulsatory movements of the stomach region which keep the fluid gut contents in constant circulation. The crop, gizzard and anterior portion of the retrocurrent passage of the pylorus comminute the food. Amebocytes present in the gut contents appear to aid in digestion. Soluble and fine particles of food pass through the pyloric filter into the liver where it is assimilated by the digestive cells. Assimilation also occurs in the pylorus and absorption possibly in the intestine. There is some evidence that the pulsatory movements of the stomach region cease during the passage of the gizzard and the liver strings.

LITERATURE CITED

AMAUDRUT, A., 1898. La partie antérieure du tube digestif et la torsion chez les mollusques gastéropodes. *Ann. sci. nat.*, **7**: 1–291.

ANSON, M. L., 1938. The estimation of pepsin, trypsin, papain and cathepsin with hemoglobin. *Jour. Gen. Physiol.*, **22**: 79.

BAECKER, R., 1932. Die Mikromorphologie von *Helix pomatia* und einigen anderen Stylommatophoren. *Zs. Ges. Anat. Abt. III. Ergeb. Anat. u. Entwicklungsgesch.* **29**: 449–585.

BAKER, F. C., 1900. The gross anatomy of Limnaea emarginata variety mighelsi Binney. *Bull. Chicago Acad. Sci.*, **2**: 191–211.

BAKER, F. C., 1911. The Lymnaeidae of North and Middle America, recent and fossil. *Special Publ. 3, Chicago Acad. Sci.*

BARFURTH, D., 1880. Die "Leber" der Gastropoden, ein Hepatopancreas. *Zool. Anz.*, **3**: 499–502.

BARFURTH, D., 1881. Der Kalk in der Leber der Helicinen und seine biologische Bedeutung. *Zool. Anz.*, **4**: 20–23.

BARFURTH, D., 1883a. Der phosphorsaure Kalk der Gastropoden Leber. *Biol. Centralbl.*, **3**: 435–439.

BARFURTH, D., 1883b. Ueber den Bau die Tätigkeit der Gastropodenleber. *Arch. mikr. Anat., Anat.*, **22**: 473–524.

BERNARD, A. AND V. BONNET, 1930. Composition minérale de l'hémolymphe et étude d'une solution physiologique pour l'escargot (Helix pomatia). *C. R. soc. biol.*, **103**: 1119–1120.

BRADLEY, H. C., 1938. On toluene in autolysis. *Physiol Rev.*, **18**: 173.

CARRIKER, M. R. 1943a. Variability, developmental changes and denticle-replacement in the radula of Lymnae stagnalis appressa Say. *Nautilus*, **57**: 52-59.

CARRIKER, M. R., 1943b. On the structure and function of the proboscis in the common oyster drill, Urosalpinx cinerea Say. *Jour. Morph.*, **73**: 441–498.

CARRIKER, M. R., 1945. Morphology of the alimentary system of the snail Lymnaea stagnalis appressa Say. *Trans. Wis. Acad. Sci.*, **38**.

CARRIKER, M. R. AND N. M. BILSTAD, 1946. Histology of the alimentary system of the snail, Lymnaea stagnalis appressa Say. *Trans. Micros. Soc.*, **65** (3).

COLTON, H. S., 1908. Some effects of environment on the growth of Lymnaea columella Say. *Proc. Acad. Nat. Sci. Philadelphia*, **60**: 410–448.

CUÉNOT, M. L., 1892. Études physiologiques sur les Gastéropodes Pulmonés. *Arch. Biol.*, **12**: 686–740.

CUVIER, G., 1817. *Mémoires pour servir a l'histoire et a l'anatomie des mollusques.* Paris (Unavailable).

DUVAL, M., 1928. The molecular concentration of the blood of some fresh water molluscs. Role of Carbonates. *Ann. physiol. physicochim. biol.*, **4**: 27–43.

ENRIQUES, P., 1901. Il fegato di molluschi e le sue funzioni. *Mittlg. Zool. Station Neapel*, **15**: 281–407.

ENRIQUES, P., 1902. Le foie des mollusques et ses fonctions. *Acch. ital. Biol.*, **37**: 177–199.

FAUST, E. C., 1920. Pathological changes in the gastropod liver produced by fluke infection. *Johns Hopkins Hosp. Bull.*, **31**: 79–84.

FOLIN, O. AND V. CIOCALTEAU, 1927. On tyrosine and tryptophane determinations in proteins. *Jour. Biol. Chem.*, **73**: 627–650.

FRENZEL, J., 1886. Mikrographie der Mitteldarmdruse (Leber) der Mollusken. I. Allgemeine Morphologie und Physiology des Drusenepithels. *Nova Acta Acad. Caesareae Leop.-Carol. Germ. Nat. Cur.*, **48**: 81-296.

FRETTER, V., 1943. Studies on the functional morphology and embryology of Onchidella celtica (Forbes and Hanley) and their bearings on its relationships. *Jour. Mar. Biol. Assoc. U. K.*, **25**: 685–720.

GARTENAUER, H. M., 1875. *Über den Darmkanal einiger einheimischen Gasteropoden. Inaug.-Dissert. Strassburg* (Unavailable).

GEDDES, 1879. On the mechanism of the odontophore in certain Mollusca. *Trans. Zool. Soc. London*, **10**: 485–491.

GRÜNBAUM, S., 1913. Sur la cellule calcigère et ses corpuscules dans le foie d'Helix. *C. R. soc. biol.*, **75**: 208–210.

HAWK, P. B. AND O. BERGEIM, 1937. *Practical physiological chemistry*. 11th. ed., Philadelphia.

HEIDERMANNS, CURT, 1924. Über den Muskelmagen der Süsswasserlungenschnecken. *Zool. Jahrb. (Abt. Allg. Zool. Physiol.)*, **41**: 335–424.

HOWELLS, H. H., 1942. The structure and function of the alimentary canal of *Aplysia punctata*. *Q. J. Microsc. Sci.*, **83**: 357–397.

HURST, C. T., 1927. Structural and functional changes produced in the gastropod mollusc, Physa occidentalis, in the case of parasitism by the larvae of Echinostoma revolutum. *Univ. Calif. Publ. Zool.*, **29**: 321–404.

KRIJGSMAN, B. J., 1925. Arbeitsrhythmus der Verdauungsdrüsen bei Helix pomatia L. *Zs. vergl. Physiol.*, **2**: 264–296.

KRIJGSMAN, B. J., 1928. Arbeitsrhythmus der Verdauungsdrüsen be Helix pomatia L. II. Teil: Sekretion, Resorption und Phagocytose. *Zs. vergl. Physiol.*, **8**: 187–280.

MERTON, H., 1923. Studien über Flimmerbewegung. *Pflügers Arch. Physiol.*, **198**: 1–28.

MOORE, H. B., 1931. The systematic value of a study of molluscan faeces. *Proc. Malac. Soc. London*, **19**: 281–290.

MOQUIN-TANDON, 1885. *Histoire naturelle des Mollusques terrestres et fluviatiles de France*. Paris.

NOLAND, L. E. AND M. R. CARRIKER, 1936. Observations on the biology of the snail Lymnaea stagnalis appressa during twenty generations in laboratory culture. *Amer. Midland Nat.* (In press).

PECZENIK, O., 1925. Über intracellulare Eiweissverdauung in der Mitteldarmdrüse von Limnaea. *Ztschr. wiss. Biol. Abt. C. Vgl. Physiol.*, **2**: 215–225.

PELSENEER, P., 1935. *Essai d'ethologie zoologique d'après l'étude des Mollusques*. Bruxelles.

PIERON, H., 1908. La localisation du sens de discrimination alimentaire chez les Limnées *C. R. Acad. Sci. Paris*, **147**: 279–280.

SEMPER, C., 1857. Beiträge zur Anatomie und Physiologie der Pulmonaten. *Ztschr. wiss. Zool.*, **8**: 340–399.

WALTER, H., 1906. The behavior of the pond snail, Lymnaea elodes Say. *Cold Spring Harbor Monog. No. 6*, Inst. Arts Sci., Brooklyn, New York.

WETHERBY, A. G., 1879. Notes on some new or little known North American Limnaeidae. *Jour. Cin. Soc. Nat. Hist.*, **2**: 93–100.

WHITFIELD, R. P., 1882. Description of Lymnaea megasoma Say, with an account of changes produced in offspring by unfavorable conditions of life. *Bull. Amer. Mus. Nat. Hist.*, **1**: 29–38.

WOODWARD, M., 1895. On the anatomy of Natalina caffra Fer., with special reference to the buccal mass. *Proc. Malac. Soc. London*, **1**: 270–277.

YONGE, C. M., 1925. The hydrogen ion concentration in the gut of certain lamellibranchs and gastropods. *Jour. Mar. Biol. Assoc. Plymouth*, NS **13**: 938–952.

YONGE, C. M., 1935. On some aspects of digestion in ciliary feeding animals. *Jour. Mar. Biol. Assoc. Plymouth*, **20**: 341–346.

YONGE, C. M., 1936. Evolution and adaptation in the digestive system of the Metazoa. *Biol. Rev.*, **12**: 87–115.

TEMPORARY PAIR FORMATION IN PARAMECIUM BURSARIA[1]

TZE-TUAN CHEN

Department of Zoology, University of California, Los Angeles

In *Paramecium bursaria*, the two members of a conjugating pair normally remain united twenty to thirty-eight or more hours. During this time various nuclear processes take place, including three pregamic divisions, exchange and fusion of pronuclei, and three post-zygotic divisions. Clones that are capable of undergoing normal conjugation as described above are called "normal clones."

But there are some clones of this species which are abnormal[2] in that when they are mixed with normal clones the pairs formed are not lasting but separate within a few hours. An examination was made of such temporary pairs in order to discover what nuclear or other changes occur in them.

Fourteen clones of *Paramecium bursaria*, all belonging to Variety I, have been used in the present study. These clones, all of which were collected in nature, are listed in Table I with data on each clone including (1) the mating type to which it belongs and (2) the locality where it was collected.

TABLE I

Clones of Paramecium bursaria *employed in study of temporary pair formation*

Clone number	Original designation of clone	Mating type	Locality collected
1	SAa5	A	Santa Ana River, Cal.
2	Or3	A	Vicinity of Capistrano, Cal.
3	SGa3	A	San Gabriel River, Cal.
4	BG35	A	Los Angeles, Cal.
5	La3	B	Laguna Canyon, Cal.
6	SAa7	B	Santa Ana River, Cal.
7	UC13	B	Los Angeles, Cal.
8	BH2	B	Beverly Hills, Cal.
9	SAa4	D	Santa Ana River, Cal.
10	LP10	D	Lone Pine, Cal.
11	UC14	D	Los Angeles, Cal.
12	SAa1	C	Santa Ana River, Cal.
13	BH7	C	Beverly Hills, Cal.
14	BH101	C	Beverly Hills, Cal.

Clones 1–11 are normal clones in that they are capable of undergoing normal conjugation. Clones 12–14 are abnormal clones in that when they are mixed with normal clones the pairs formed are not lasting but separate within a few hours.

[1] This work was aided by grants from the Committee for Research in Problems of Sex, National Research Council; and from the Joseph Henry Fund of the National Academy of Sciences.

[2] These clones are considered abnormal here only because they are incapable of taking part in the formation of lasting pairs when they are mixed with other, normal clones.

The animals were cultured in essentially the manner described by Jennings (1939). For cytological study the animals were fixed in Schaudinn's fluid containing glacial acetic acid, stained in iron hematoxylin, and destained in saturated aqueous solution of picric acid, following the technique the writer has described (Chen, 1944).

Experimental Studies

Most of the present work was done with the two abnormal clones (BH7, SAa1), although some study was also made on a third abnormal clone (BH101). All of these three abnormal clones belong to mating type C of Variety I. These abnormal clones were mixed with normal clones. Eleven such normal clones (all belonging to Variety I) were used. Four of these normal clones belong to mating type A; four to type B; and three to type D (see Table I).

As an example of the phenomenon of temporary pair formation, the reaction between the abnormal clone SAa1 and the normal clone UC13 will be described. On November 27, 1940, a large number of animals belonging to each of these two clones were mixed at about eleven o'clock in the morning. Strong agglutinative mating reaction occurred almost immediately. Half an hour after mixture, pairs were being formed. An hour after mixture (about noon) many pairs were formed. But in the early afternoon the pairs broke apart into single animals. By five o'clock all but a few pairs had separated. By evening all had separated.

Such temporary pair formation was also observed when the abnormal clone SAa1 was mixed with the following normal clones: Or3, SGa3, SAa5, La3, SAa7, BH2, SAa4, LP10, and UC14; or when the abnormal clone BH7 was mixed with the normal clone LP10; or when the abnormal clone BH101 was mixed with the normal clone BG35.

If such a mixture was placed in a moist chamber and kept from drying (with occasional replacement of the fluid that evaporated), the typical agglutinative mating reaction and temporary pair formation recurred the following day and almost daily over a period of many days. Some such mixtures were kept under daily observation over a period of nineteen days. The following is the characteristic daily behavior of the animals in such a mixture. The agglutinative mating reaction occurs in the late morning. By noon, many pairs are formed. These pairs persist for a few hours. Between four and six o'clock in the afternoon only a few pairs are found. In the early evening one or two pairs may remain; none can be found after nine o'clock in the evening.

Cytological Studies

Nuclear conditions in the clones that form only temporary pairs

The writer has made a cytological study of twenty-one abnormal clones, including the two clones BH7 and SAa1, and nineteen of the twenty-two such clones described by Jennings (1944). It was found that fifteen of these clones possess micronuclei, while six appear to be amicronucleate.

Thus the amicronucleate condition is not the general cause of the peculiar behavior of these abnormal clones. It is probable that the persistence of the amicronucleate condition is a *result* of the inability to conjugate and acquire a micronucleus, rather than the cause of it. Apparently there are conjugating and non-conjugating

races of amicronucleate ciliates. In nature those that can conjugate do so and acquire a micronucleus, leaving in the amicronucleate condition only those incapable of conjugation. In my experience with *P. bursaria*, which includes a study of the nuclei and chromosomes of many clones (collected from different parts of the United States, Canada, Russia, England, Ireland, and Czechoslovakia), the only amicronucleate animals found in nature are those which cannot conjugate. Since they cannot conjugate, it is likely that such clones will be permanently amicronucleate. In nature any amicronucleate animal that can conjugate would not remain amicronucleate for long, since it would become micronucleate after mating with a normal animal from whom it receives a pronucleus as a result of conjugation (Chen, 1940).

Amicronucleate animals that can conjugate have been found in *P. bursaria* (Chen, 1940) [3] and in *Euplotes patella* (Kimball, 1941). They arose spontaneously in laboratory cultures.

Nuclear changes in temporary pair formation

To determine whether nuclear changes occur in temporary pair formation, a series of preparations were made, in December, 1940, of temporary pairs (abnormal clone SAa1 × normal clone UC13) [4] and a number of separated animals belonging to the latter clone. The material included pairs 5 to 6 hours after onset of temporary mating, separated animals a few hours after separation, 13 to 17 hours after separation, and 21 hours after separation. The micronuclei in these temporary pairs and separated animals were compared with the micronuclei of vegetative animals of clone UC13 (not mixed with any other clone). It was found that micronuclei in the majority of the temporary pairs and of the separated animals were slightly swollen. In some, no nuclear changes were apparent.

In June, 1943, a series of preparations were made of temporary pairs (abnormal clone BH101 × normal clone BG35) [5] and a number of separated animals belonging

[3] The writer has recently found some additional cases of conjugation between amicronucleate and normal animals in *Paramecium bursaria*, in Variety III. (Normal nuclear changes occur in the conjugants having the micronuclei.) These amicronucleate animals arose spontaneously in laboratory cultures.

Schwartz (1939) in a brief preliminary paper reported "conjugation" in *Paramecium bursaria* between amicronucleate and normal animals and between two amicronucleate animals. In view of the lack of details in this report, it is impossible to tell whether temporary or lasting pair formation took place.

[4] Clone SAa1 appears to be amicronucleate; clone UC13 has a deeply staining micronucleus.

[5] Clone BH101 has a small, lightly staining micronucleus; clone BG35 has a relatively large, deeply staining micronucleus.

EXPLANATION OF FIGURES

FIGURES 1–34. Micronuclei of animals belonging to clone UC13 before, during, and after temporary pairing with animals of clone BH7 (drawn by Mr. Earl Nielsen). All drawings were made with a camera lucida. × 3,300.

FIGURES 1–5. Resting micronuclei of vegetative animals.

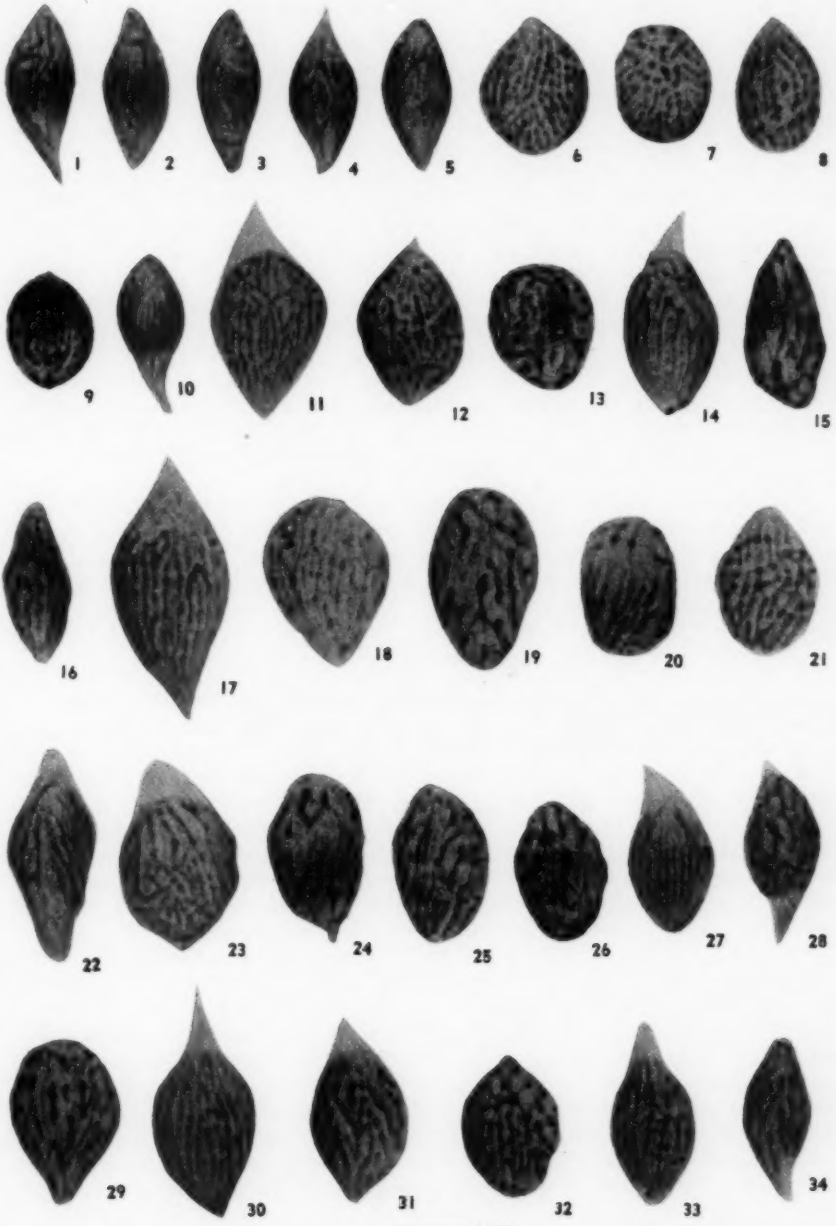
FIGURES 6–10. Micronuclei in the members of temporary pairs 4 hours after onset of pairing.

FIGURES 11–16. Micronuclei in the separated animals 18 hours after separation.

FIGURES 17–22. Micronuclei in the separated animals 30 hours after separation.

FIGURES 23–28. Micronuclei in the separated animals 42 hours after separation.

FIGURES 29–34. Micronuclei in the separated animals 51 hours after separation.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34

FIGURES 1–34.

to the latter clone. The material included pairs 3 to 4 hours after onset of temporary pairing, and separated animals 2 hours after separation, and a day after separation. It was found that the micronuclei in the majority or most of the temporary pairs and separated animals were slightly swollen. In others no nuclear changes were apparent.

In October, 1944, a series of preparations were made of the temporary pairs (abnormal clone BH7 × normal clone UC13) [6] and separated animals belonging to the latter clone. The material included pairs 4 hours after onset of temporary mating, and separated animals 7 hours after separation, 18 hours after separation, 30 hours after separation, 42 hours after separation, 51 hours after separation. A series of preparations of vegetative animals of clone UC13 (not mixed with any other clone) were used as controls (Figs. 1–5). It was found that the micronuclei in nearly all of the temporary pairs and separated animals were slightly but noticeably swollen (Figs. 6–34). This is true even of the separated animals 51 hours after separation (Figs. 29–34), indicating that the physiological effect of the contact between the animals in temporary pairing (as shown by the swelling of the micronucleus) is of long duration.

General Relations

The temporary pair formation described in the present paper is similar to that reported by Sonneborn (1942) in *P. aurelia* and by Jennings (1944) in *P. bursaria*. Sonneborn (1942) concluded from his data that cell adhesion occurring in the initial stage of the mating reaction and cell fusion occurring during subsequent conjugation are due to two different mechanisms.

Summary and Conclusions

1. In normal conjugation of *Paramecium bursaria*, the two members of each pair remain united for 20 to 38 or more hours, during which time various nuclear processes take place including three pregamic divisions, exchange and fusion of pronuclei, and three post-zygotic divisions. Clones that are capable of undergoing normal conjugation as described above are called "normal clones."

2. Some clones of this species are abnormal in that when they are mixed with normal clones the pairs formed are not lasting but separate within a few hours.

3. In temporary pair formation, the animals of diverse mating types when mixed exhibit the typical agglutinative mating reaction. Within an hour many pairs are formed but in a few hours these pairs break apart into single animals.

4. If such a mixture is placed in a moist chamber and kept from drying (with occasional replacement of fluid that evaporates) such agglutinative mating reaction and temporary pair formation will recur daily over a period of many days.

5. Cytological study of 21 such abnormal clones shows that most of these clones have micronuclei; some appear to be amicronucleate. Therefore, amicronucleate condition cannot explain the incapacity for taking part in the formation of lasting pairs. It is probable that the persistence of the amicronucleate condition is a *result* of the inability to conjugate and acquire a micronucleus rather than the cause of it.

6. In temporary pair formation, there are no conspicuous nuclear changes either in the pairs or in the animals after their separation. In the majority of the tempo-

[6] Clone BH7 appears to be amicronucleate.

rary pairs and separated animals, there is, however, a slight swelling of the micronuclei. This swelling persists for a considerable length of time after the separation of the animals, indicating that the physiological effect of the contact between the animals in temporary mating (as shown by the swelling of the micronuclei) is of long duration.

LITERATURE CITED

CHEN, T. T., 1940. Conjugation in Paramecium bursaria between animals with diverse nuclear constitutions. *Jour. Hered.*, **31**: 185–196.

CHEN, T. T., 1944. Staining nuclei and chromosomes in Protozoa. *Stain Techn.*, **19**: 83–90.

JENNINGS, H. S., 1939. Genetics of Paramecium bursaria. I. Mating types and groups, their interrelations and distribution; mating behavior and self-sterility. *Genetics*, **24**: 202–233.

JENNINGS, H. S., 1944. Paramecium bursaria: life history. I. Immaturity, maturity and age. *Biol. Bull.*, **86**: 131–145.

KIMBALL, R. F., 1941. Double animals and amicronucleate animals in Euplotes patella with particular reference to their conjugation. *Jour. Exp. Zool.*, **86**: 1–32.

SCHWARTZ, V., 1939. Konjugation micronucleusloser Paramaecien. *Naturwiss.*, **27**: 724.

SONNEBORN, T. M., 1942. Evidence for two distinct mechanisms in the mating reaction of Paramecium aurelia. *Anat. Rec.*, **84**: 542–543.